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NATURAL DYEING WITH PLANTS IN MICHIGAN

Jane I. LaRue

Matthaei Botanical Gardens
University of Michigan, Ann Arbor

The revival of interest in natural dyeing is one facet of the current popular arts and crafts craze; it provides pleasure and satisfies an urge for self-expression. Coloring agents occurring in nature include the following types: *Animal,* such as cochineal, the dried bodies of the insect, *Dactylopius coccus,* which feeds on the cactus, *Nopalea coccinellifera. Vegetable,* such as black walnut hulls. *Mineral,* such as iron rust.

Most natural dyes are derived from plants, and in this article we shall concentrate on plant dyes, especially those obtained from plants which may be collected in Michigan. Most of my experience has been with dye plants collected in Kalkaska County where our family owns property. My aim is to provide enough basic information to enable persons to carry out some elementary dye-plant projects without further reference. However, much has been published on this subject, and so a list of recommended references will be provided. You will note that most are available in paperback and, hence, the cost is modest.

Natural dyeing was actually practiced in prehistoric times, but dyes used then were only non-permanent stains from fruits, flowers, and bark. The ancient Phoenicians are said to have originated the prized purple dye extracted from Mediterranean shell fish of the genera *Purpura* and *Murex.* Colored fabrics were much in demand in ancient Greece and Rome where methods of dyeing with plants were perfected. The writings of Dioscorides, the famous Greek physician, and Pliny the Elder, the Roman naturalist, both include descriptions of ancient dye plants and methods used in their day. However, after the 16th Century, European dyeing methods appear to have been derived from India, where they practiced the art as early as 2500 B.C.

The universal use of natural dyes continued until 1856 when a lavender dye made from aniline, a coal-tar derivative, was discovered by Sir William Henry Perkin. This mauve color caused great excitement, and eventually synthetic aniline dyes replaced natural dyes in commerce. Some rural folk interested in handcrafts continued to use natural materials to achieve the soft, rich colors made possible with the old methods. We are indebted to craftspeople of the southern mountain areas for preserving the traditions associated with the art of natural dyeing in the U.S.

EQUIPMENT

The Brooklyn Botanic Garden handbook, *Dye Plants and Dyeing* (p. 10), lists the following equipment to carry out a dye project. I have added a few items which I find useful.

Soft water (rainwater is ideal).
A stainless steel or enamel dye pot.

Scales to weigh plant parts, fabric or yarn, and mordants.
Cooking thermometer.
Pyrex measuring pitchers in cup and quart sizes.
Plastic spoons for mordants.
Glass stirring rods or wooden stirrers (if wooden, a separate one must be used for each color).
Cheesecloth or a stainless steel sieve, for straining plant material out of dye solution.
Mild soap.
Buckets for rinsing.
Kitchen timer.
Rubber gloves.

MORDANTS AND THEIR USES

Dyes may be classified into two groups: 1. *Substantive dyes* which impart color without the use of a mordant. Lichens, black walnut hulls, sumac fruit, and oak galls belong to this group. However, mordants can be used with these dyes to change the color given. This will be discussed later. 2. *Adjective dyes* which require treating the fiber to enable it to absorb and/or retain the color. That treatment is called *mordanting.*

Commonly used mordants are metallic salts of alum, iron, chrome, copper, and tin. Some other chemicals used for this purpose are acetic acid, ammonia, tannic acid, and tartaric acid. The term "mordant" is derived from the Latin *mordere* which means "to bite" and refers to the fact that a mordant binds the colors to the fiber. Wool is a protein with functional groups that react with the mordant which in turn attracts the dye. Thus the mordant is acting as a link between the fiber and the dye. This offers a simple explanation of the chemical reactions involved in natural dyeing, but textile chemistry is a specialized field and beyond the scope of this article.

The use of different mordants with the same dye changes the resultant color; for example, an alum mordant used with pine cones produces beige, whereas an iron mordant results in a dark-brown shade. When used as a mordant, alum does not change the natural color; neither does tin, but it produces a brighter shade. The material from which the dye kettle is made can affect the results. Using an iron or copper kettle, as colonial women did, is similar to using an iron or copper mordant. The dull shades of clothing worn by our ancestors resulted from the use of rusty iron kettles as dye pots. Containers composed of inert material, such as stainless steel or enamel, do not react with the dye, and so they are used with an alum mordant to produce the natural color of any plant material.

According to Douglas Leechman, in *Vegetable Dyes from North American Plants* (p. 13), there are several methods of mordanting, before dyeing, after dyeing, during dyeing, and both before and after. I have had experience with premordanting as well as simultaneous mordanting and dyeing. I prefer to premordant several small skeins of wool at a time and keep them until needed. That way, I can test several mordants in one dye pot and save time.

It is necessary to use a scheme to enable one to distinguish between the mordants used on the various skeins. Many dyers use a system of knots to designate the mordants being used; one knot for alum, two for chrome, etc. According to Beth Pennington, instructor of natural dyeing at the Henry Ford Museum, labels made from masking tape marked with a black marking pen work out very well. She says that the ink does not bleed or affect the results in any way.

Since the primary function of a mordant is to bind the dye to the fiber, it is important to follow a recipe when desiring a specific hue. Lovely colors may result when experimenting with different mordants, but the colorfastness and durability of the fiber may be adversely affected if the dye and mordant are incompatible (Adrosko, 1968, p. 61). For long-lasting results, follow a tested recipe.

Both wool and silk may be easily mordanted, but cotton and linen require a more involved process. Wool is by far the best fiber to work with and should be the choice of the novice. Wool may be dyed before it is spun or after. Fleece must be washed thoroughly to remove the lanolin before it will accept either mordant or dye, but yarn should be washed as well to remove any oil added to facilitate spinning. You may use natural yarn untreated with chemicals or regular commercially treated white yarn. I personally prefer to use untreated natural yarn. A list of suppliers of materials appears at the end of this article.

DIRECTIONS FOR MORDANTING WOOL WITH ALUM

(Directions apply to one pound of dry wool).

3-4 oz. alum (aluminum potassium sulfate)*
1 oz. cream of tartar**

Dissolve the alum in warm water and add to four gallons of soft water at about 160°F. Then dissolve the cream of tartar in warm water and add to the bath also. Yarn should be wound into skeins tied in three or four places with cotton string to prevent tangling and wetted before mordanting. Wet the wool gradually, bringing it up to about the same temperature as the mordant solution before immersing it. (Always avoid abrupt changes in water temperature when working with wool in order to prevent matting and shrinking. When removing water, always squeeze rather than twist the wool in order to prevent undue wrinkling.)

Gradually raise the temperature to the boiling point (212°F), but do not allow it to go beyond. Simmer for three-quarters of an hour for fine wool and one hour for heavy wool. Wool should be agitated in the bath in order to insure complete penetration of the mordant. Remove wool from the pot temporarily while adding boiling water to make up for evaporation during simmering. When the required time has elapsed, allow wool to cool in the bath before removing. Wool may be used directly after mordanting, rinsed or unrinsed, or it may be dried in a bag over a long period of time, in which case it should be rinsed before dyeing.

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*Not the grocery store alum (ammonium aluminum sulfate), though it may be substituted, if aluminum potassium sulfate is not readily available.

**Cream of tartar makes colors bright and clear.

Other commonly used mordants include chrome (potassium dichromate), tin (stannous chloride), copper (copper sulfate), and iron (ferrous sulfate). Chrome is difficult to work with because oxidation on exposure to light can result in streaking. Tin may be added to the pot towards the end of the dyeing period to brighten the color of the goods. Such a procedure is known as "blooming." Tin must be used sparingly since an excess of tin causes wool to become brittle. Iron, known as copperas to dyers, is likely to harden wool while darkening it. It is often added along with cream of tartar to the dye pot after the wool has been simmered for a while; this process is called "saddening." Another feature of some mordants necessitating extreme care is toxicity. Copper sulfate is harmful or fatal if swallowed and may cause skin irritation. The potassium dichromate label warns that hazardous dust may cause burns or external ulcers if contacted. When working with chemicals, one should take normal precautions and wear rubber gloves. All chemicals should be stored out of reach of small children.

COLLECTION AND PREPARATION OF PLANT MATERIAL

According to Mary Frances Davidson in *The Dye-Pot* (p. 5), the following quantities of plant materials are required to dye one pound of wool:

Bark–one peck, finely chopped
Leaves–three-fourths peck, dried
Hulls–one peck
Flowers–one and one-half quarts, dried; one and one-half pecks, fresh.

If the full amount is not available, use as much as you can collect and expect a lighter color. As a general rule, it is convenient to remember that one peck of dye material per pound of wool yields a medium value. (Value is a term used to denote the lightness or darkness of a color on a scale ranging from black to white.) To vary the value, one must use a different amount of wool or plant material. The volume of water does not affect the resultant color as long as the goods turn freely in the pot; however the kind of water used is very important. Rainwater gives the brightest, clearest colors, as it is free of dissolved mineral salts. Hard water must be softened. If in doubt about the hardness of your water supply, you can obtain information from your local water department or send a sample to a laboratory for analysis. Chemicals used to soften water are available at grocery stores. Sal soda, also called washing soda, may be used for this purpose.

Other factors, aside from the amount of plant material used, influence the dye obtained from a particular species. It is usually best to collect plant material when it is approaching maturity, if other than flowers are to be used. Flowers are best collected when beginning to open. After they have been exposed to rain and sun, their dyeing qualities are diminished. Rita Adrosko, in *Natural Dyes in the United States* (p. 61), attributes color variation in natural dyeing to "differences in growing conditions in the area in which the plants are grown, climatic conditions, and quality of soil." Duplicating a shade is almost impossible, and so it is imperative to dye all goods for a specific project at the same time.

In the interest of conservation, when collecting dye plants, do not take them all from the same area. Some plants such as lichens grow so slowly that only the commonest species should be gathered. Of course, plants on the protected list should not be used. (See Helen Smith's *Michigan Wildflowers* for a listing.) If cultivated in one's own garden, plants such as bloodroot *(Sanguinaria canadensis)* may be thinned in order to obtain roots for natural dyeing. Bark and roots may be scavenged when trees are cut to clear land at a construction site. The pruning of trees and shrubs also provides an opportunity to gather dye materials.

Most plants may be used either fresh or dried, but I find that the color is brighter from fresh material. Flowers may be hung upside down to dry in a shady, well ventilated room. Leaves may be spread out on newspapers or a screen for drying. Special care must be taken when drying roots, bark, berries, and lichens in order to prevent molding. When the material is completely dry, it should be placed in a properly labelled paper bag and stored in a dry place.

It is important to note that the color of a flower gives no indication of the resultant color of dye. Contrary to expectation, a red flower will not necessarily yield a reddish hue. In my experience thus far, I have been unable to obtain a red or pink hue from locally collected plants. Cochineal gives beautiful shades of red, but one must depend upon commercial sources for that dye.

Black is a difficult color to achieve from natural dyes, and so it has been used as a criterion of one's skill in dyeing. A true black requires a combination of dyes rather than only one: Thus a black recipe might use logwood and sumac for their black tones in addition to fustic (for yellow) and a metallic oxide such as copperas which in the process of oxidation fixes the black (Adrosko, p. 47). Jet black is not often necessary, and navy blue may be substituted for it. But, if only black will do, I understand that an iron pot with walnut hulls and a pinch of ferrous sulfate will give good results.

PREPARATION OF WOOL

We have already noted the necessity for washing wool thoroughly before dyeing. A neutral soap such as that used for washing lingerie and fine woolens is recommended. First, dissolve 2 tablespoons of soap flakes in each gallon of lukewarm water used. Wash the wool thoroughly, squeeze out suds, and rinse several times until water is clear. If the wool is very greasy, it should be washed a second time following the same procedure.

PREPARATION OF DYE-BATH

Crush or chop the dye-plant material, cover with soft water, and soak overnight in a glass or enamel container. Boil material for one hour and strain through several layers of cheese cloth or a stainless steel sieve. If the volume of liquid is not adequate for the amount of wool to be dyed, add water bringing the total to four gallons (for one pound of dry wool).

DYEING

The dye-bath should be lukewarm when the dyeing process begins. Rinse premordanted wool well in lukewarm water and squeeze out excess water before entering it into the dye-pot. Wool should be agitated and opened out exposing all parts evenly to the dye. Raise the temperature gradually to boiling and keep simmering for one-half hour or more. If water evaporates during the process, remove wool while adding boiling water to restore the original level. Be sure to stir well before replacing the wool.

You may check the color of your wool from time to time keeping in mind that wet wool is darker in color than comparable dry wool. After the dyeing is finished, rinse the wool in water of the same temperature as the dye-bath, and transfer it to a slightly cooler water bath. Continue to rinse in a series of cooler baths until the water runs clear. Finally, squeeze the wool gently and roll it in a towel to absorb excess moisture. Large skeins may be spun dry for about one minute in an automatic washer. Hang wool in the shade to dry.

After mastering the technique of dyeing with one bath, you may want to experiment with top-dyeing which involves dipping wool into two different dye-baths. For example, top-dyeing a clear yellow with indigo will give a good green. To get the best results, you must start with dye-baths giving clear colors. Long simmering often produces dull colors unsuitable for top-dyeing. Indigo and madder are often used in combination with other dyes for the purpose of top-dyeing. An excellent chart with directions for top-dyeing with these dyestuffs may be found in Adrosko (1968, pp. 107-109). Indigo, the most important dye used in America before the advent of aniline dyes, is a blue dye extracted from the leaves of *Indigofera tinctoria,* a leguminous plant long grown for its staining property. The process of deriving the blue coloring agent is long and complex involving the use of other materials to induce fermentation.* Thus indigo is one of the dyes which must be purchased rather than cultivated or gathered in the wild. Madder is a red dye extracted from the roots of *Rubia tinctorum.* It is possible to raise this plant for such purposes, but it takes three years for the roots to mature to a stage where they are suitable for use. Synthetic indigo is now used almost exclusively even by natural dyers since it is so difficult to obtain.

DYE PLANTS

The list of potential dye plants is endless, but, over the years, some have proved to be better than others. I have only "scratched the surface" in testing available plant material. It is a fascinating and very rewarding pastime for those who plan to use natural-dyed wool for weaving, knitting, rug hooking, or some other craft. I knitted a vest using yarn dyed with goldenrod and also made a sampler with many other dyes. The incentive for pursuing this activity originally stemmed from a desire to provide an educational display at the

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*Fermentation refers to the action of bacteria as a reducing agent in the dye vat.

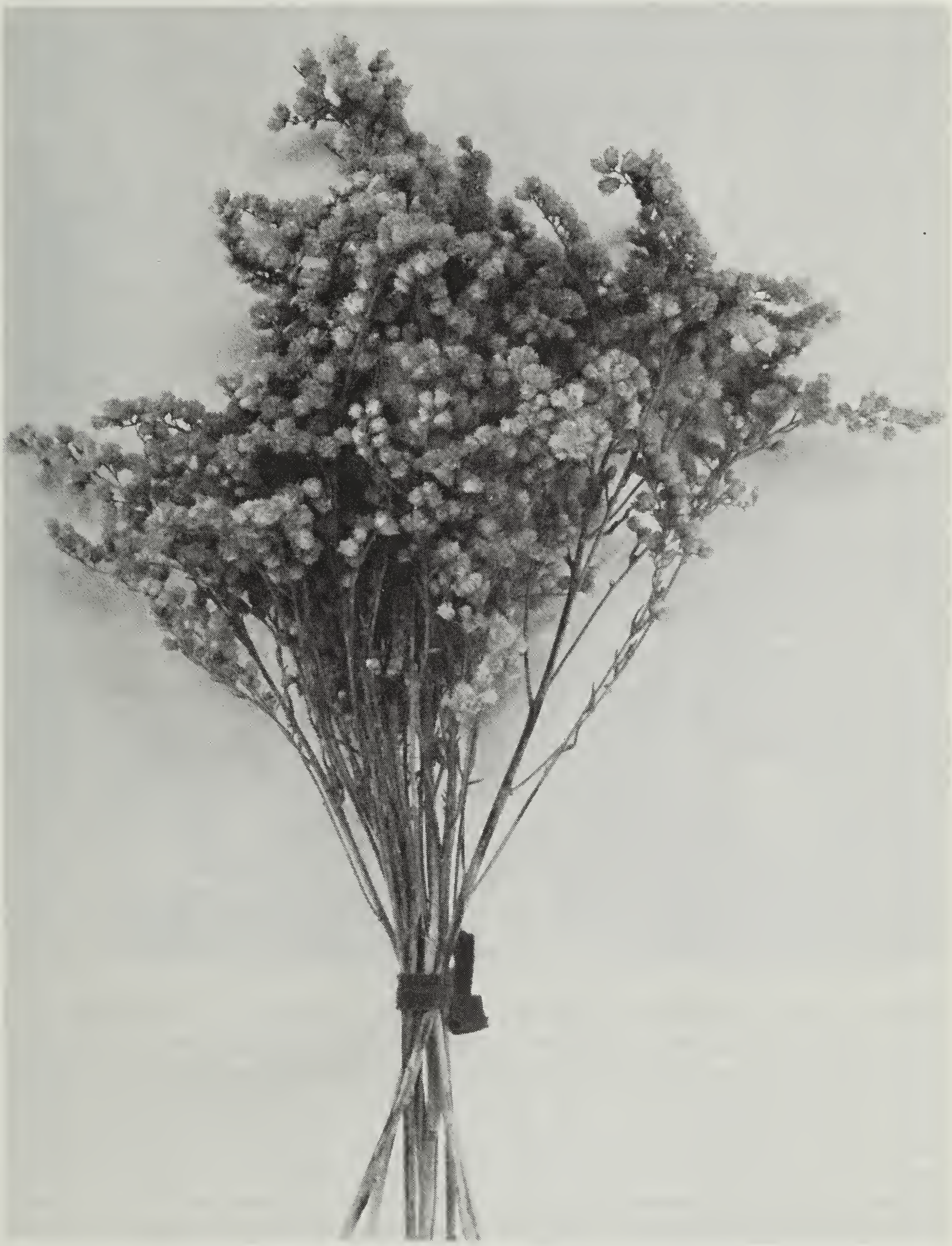

Fig. 1. Dried plants, such as this bunch of goldenrod, may be used for natural dyeing.

Botanical Gardens (of the University of Michigan), but my interest in the subject has spurred me to further study and experimentation. My introduction to the subject came in the form of a workshop conducted at the Henry Ford

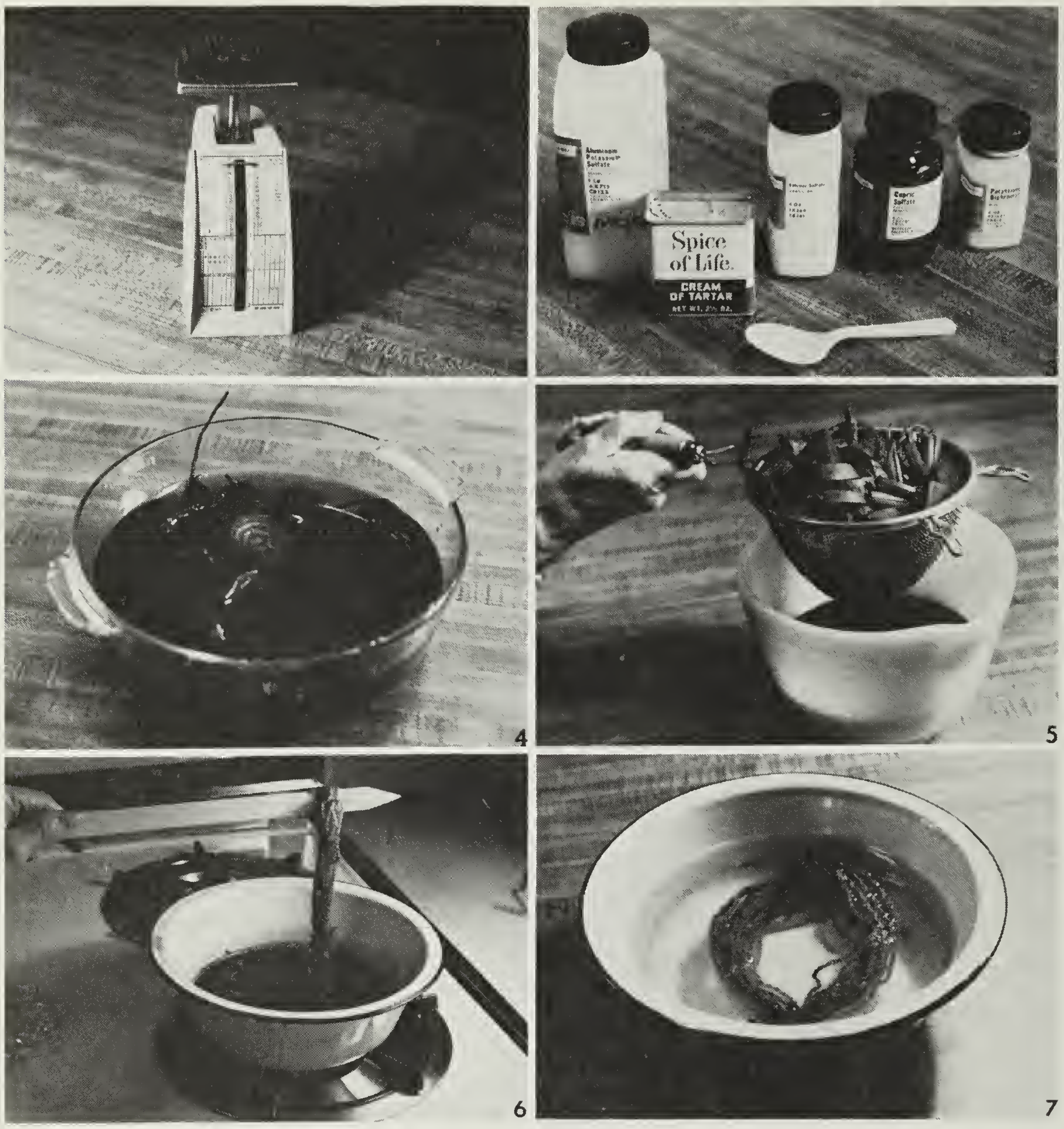

Fig. 2-7. Steps in dyeing. 2. Mordants as well as yarn or fabric may be weighed on a postal scale. 3. Some common chemicals used as mordants. Care should be used in handling chemicals as some are caustic and/or poisonous. 4. Plant material selected for dyeing should be chopped or cut up, covered with water, and soaked overnight. (Dyeing with beets is interesting to try, but the color is not fast.) 5. After boiling for about one-half hour, the plant material should be cooled and strained; the remaining liquid is the dye. 6. A glass rod is ideal for handling yarn while dyeing. If a wooden stick is used, a separate one should be reserved for each color. Note use of enamel pan. 7. After cooling the dye pot, yarn is rinsed until water runs clear. Abrupt changes in temperature of water cause shrinkage and matting of wool.

Museum in Dearborn, as part of a series offered by the Edison Institute. The rest of my work has been done independently as time permitted.

The following dye plants are some of the most available species in Michigan. I would recommend these to teachers, camp counselors, or anyone else interested in an elementary dye-plant project. A few months ago I discovered a small paperback book entitled *Let's Try Mushrooms for Color* by Miriam C. Rice. Unfortunately, I have not had adequate opportunity to try the suggested species of fungi, and so I hesitate to include any in this list. However, interested persons should refrain from experimenting with poisonous mushrooms such as amanitas.

When the dye plants listed below are used, the basic methods previously discussed should be followed. For future reference, you should keep a labeled sample of each dye lot as well as a record of the amount and kind of plant part and mordant used and the time involved in the process. Small samples may be attached to cards for easy storage. You may also want to expose a sample of each dye lot to the sun for two weeks in order to determine how well it resists fading.

Natural dyeing with some lichens produces especially beautiful colors in the rose and purple range. I have not included methods for their use, but anyone interested in following up on the subject may refer to an article entitled "A Practical Approach to the Use of Lichens" by Phyllis Yacopino in the Brooklyn Botanic Garden handbook, *Natural Plant Dyeing* (1973, pp. 29-32). Almost all lichens on boiling in water will yield beige to brown colors which are very fast. Such colors can be intensified or changed by mordanting. A few lichens, when steeped in ammonia or stale urine, produce the rose shades known as orchil dyes. A test for the latter kind of lichen involves a pink reaction when a drop of chlorine bleach is applied to the inner tissue of the lichen. The orchil shades may be altered from the bluish to the reddish range by varying the acidity. Mordants can also change the pH and thus alter the color within that range. Litmus as an indicator of the degree of acidity was originally made from lichens.

Several plant materials which I have tried produce fair colors that unfortunately are not fast, and therefore are not recommended: annatto seed; beets; fruit of blackberry, blueberry and pokeweed; and turmeric.

CULTIVATED PLANTS

BARBERRY (*Berberis* spp.). Barberry is a shrub with small yellow flowers and later red berries. It is found in landscaped areas and also in woods where it has escaped cultivation. The stem or root, fresh or dried, produces a yellow dye which is substantive but is often used with alum.–*Berberis vulgaris* and most other *Berberis* species are alternate hosts for *Puccinia graminis* spp. *tritici* which attacks wheat crops. The U.S. Dept. of Agriculture has been carrying on a campaign to eradicate barberry plants since 1918. *Berberis thunbergii,* a common decorative species, is highly resistant to wheat rust.

MARIGOLD (*Tagetes* spp.). Popular garden annuals with orange, yellow, and brown flowers, the marigolds are excellent dye plants. Lovely shades of yellow may be achieved by varying the amount of flowers used from one quart to one bushel.

POINSETTIA (*Euphorbia pulcherrima*). The colorful bracts of this traditional Christmas flower give a beige shade with alum. To gather enough to try out, you may have to ask your friends to save them for you.

WILD PLANTS

BLACK WALNUT (*Juglans nigra*). This tree grows wild in rich woods and is also cultivated for its delicious nuts and valuable brown wood. The green hulls may be used for brown shades when the nuts are ripe or may be dried for future use. The longer they are soaked in water, the darker the color. When preparing the dye, you should boil the hulls for 2½ hours. Walnut dye is substantive and needs no mordant, however alum may be used to insure colorfastness.

BRACKEN FERN (*Pteridium aquilinum*). A very common fern in northern Michigan; the fiddleheads when still coiled at the tip in spring give a yellow-green hue with alum.

FIREWEED (*Epilobium angustifolium*). Fireweed with its tall stalk bearing purple flowers grows in recently cleared areas and burned woodlands. The flowers yield a bright yellow dye when yarn pre-mordanted with alum is simmered for one-quarter of an hour.

GOLDENROD (*Solidago* spp.). This common weed is one of my favorites for the flower heads give good yellow to gold colors when used fresh or dried. Color is best when flowers are just opening up. To assure colorfastness, alum-mordanted yarn should be dyed according to the standard recipe and then set with an after-bath of potassium dichromate (1/6 ounce) and vinegar (6-7 tablespoons) for 10 minutes. Rinse both preceding and following the after-bath.

HORSETAIL (*Equisetum* spp.). These rush-like plants with jointed, often hollow stems having sheaths at the joints are often found in damp places. Following the standard recipe with alum gives a greenish-yellow which is excellent for top-dyeing with indigo to give green.

OSAGE ORANGE (*Maclura pomifera*). Introduced from Arkansas and Texas and naturalized in the north, this tree with unusual green fruit resembling an orange has been used as a hedge plant. The bark or roots when processed in the standard manner yield a deep gold. I was fortunate to receive some roots from a friend, but an extract of the bark is available from dye supply houses for those unable to obtain plant material.

PAPER BIRCH (*Betula papyrifera*). This common tree in northern Michigan is the one which provided the Indians with bark for their canoes. The inner bark gives a beige shade without any mordant. Use one pound of bark to ½ pound of wool tying crushed bark in a muslin bag and soaking overnight. The next day, boil for one hour before dyeing.

PINE CONES (*Pinus* spp.). Cones should be broken up and boiled for 3-4 hours to extract dye and then strained out. Alum-mordanted yarn is then entered and allowed to remain until desired shade is reached. Fifteen minutes in the dye bath produced a light beige for me.

SHEEP SORREL (*Rumex acetosella*). Leaves of this common weed from worn-out fields and sour soils give a pale yellow. I allowed them to ferment for two weeks before boiling to prepare the dye bath. Otherwise, the usual methods were used.

ST. JOHN'S-WORT (*Hypericum perforatum*). A pesky weed of roadsides and fields, the flowers of St. John's-wort produced a good yellow dye with the standard recipe. And Mary Frances Davidson in *The Dye Pot* says, "From its leaves, it is said that a good red dye may be obtained," but I have yet to prove the truth of that statement.

SUMAC (*Rhus typhina*). Sumac with its colorful fruit and leaves is a delight in the fall of the year in Michigan. The fruit yields a golden tan when handled in the standard manner. It is also used for fine tanning.

OTHER DYE MATERIAL USUALLY PURCHASED FROM A GROCERY STORE OR DYE SUPPLIER

COCHINEAL. As previously stated, cochineal is a dye prepared from the dried female insect bodies of *Dactylopius coccus* found on cacti in Mexico and Central America. Beautiful shades of red may be obtained by using various methods. If cochineal is not pulverized when purchased, be sure to grind it before using. For best results, soak the powder in water for twenty-four hours in preparation for dyeing. Crimson results from using wool pre-mordanted in the standard way with alum and cream of tartar in a bath with 1½-2 ounces of cochineal and 1½ teaspoons of common salt.

Another method calls for mordanting and dyeing in the same bath. Dissolve alum and cream of tartar and later add wool when water is warm. Bring it to a boil and simmer for 20 minutes. Remove wool and add cochineal. Stir until dissolved, re-enter wool, and simmer just below the boiling-point for three-quarters of an hour or until desired shade is reached. Color-fastness is good. Cochineal may be purchased in powdered form from dye suppliers such as those listed at the end of this article.

COFFEE (*Coffea arabica*). The fruits of this species native to tropical Africa are roasted and ground before we buy them, and they provide a dye which is interesting and easy to obtain. Use 1¾ pounds of ground coffee for one pound of wool. A soft beige shade is produced.

ONION (*Allium cepa*). The outer skins of onion bulbs give yellow to burnt-orange shades. This common vegetable has been in cultivation since the ancient Egyptian era and has long been a source of yellow dye for Easter eggs in Europe. Use one-half pound of Yellow Globe onion skins to dye one pound of wool a burnt-orange shade with the standard alum recipe. Omit over-night soaking. Cover skins with water and boil for 15 minutes. To get a yellow-green color, reduce amount of alum to 2 ounces and use whole onion rather than skins only. Color-fastness is fair.

TEA (*Thea sinensis*). The leaves of the tea plant, native to China, provide a flavorful beverage but may also be used for dyeing. One-half pound of tea should be used in the standard recipe. No mordant is necessary.

I wish to express appreciation to Dr. Howard Crum for information on lichen dyeing, to Beth Pennington for reading my manuscript with regard to practical aspects of dyeing, and to my husband for help with photography.

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THE CHEMICAL INHIBITION OF COMPETITORS BY SMOOTH SUMAC (RHUS GLABRA)

Andrew G. Stephenson
Department of Botany
University of Michigan, Ann Arbor, 48109

Recently, several investigators have stated that allelopathy (the deleterious effect that one plant has on another through the production of chemical retardants that escape into the environment) can affect species composition and rate of succession in abandoned fields (see Rice, 1974, for review). These investigators argue that allelopathic plants interfere with successional processes in at least three ways: by inhibiting the seed germination of potential colonizing species and species characteristic of later successional stages; by retarding the growth and establishment of some species; and by slowing the rate of available nitrogen accumulation in the soil by inhibiting nodulation in legumes and free-living nitrogen fixers (Abdul-Wahab & Rice, 1967; Blum & Rice, 1969; Muller, 1969; Muller, Lorber & Haley, 1968; Rice, 1964, 1965c, 1968; Wilson & Rice, 1968).

Rhus glabra L. (Smooth Sumac) is a characteristic woody member of mid-successional communities on abandoned fields in Michigan (Beckwith, 1954). I have often observed that there are fewer species under *R. glabra* clones as compared with areas adjoining the clones and as compared with other areas of comparable shading in the community. A close relative of Smooth Sumac, *Rhus copallina* L., has been reported to be allelopathic (Blum & Rice, 1969). Smooth Sumac also contains gallic and tannic acids, which inhibit nodulation in legumes when these substances are released into the soil (Rice, 1965a; 1965b; Rice & Parenti, 1967). Consequently, I wish to investigate whether *R. glabra* is allelopathic. In this paper, I attempt to show that viable seeds are present in the soil under Smooth Sumac clones, and when released from the influences of the clone they will germinate. Furthermore, I show that the number of species under a clone increases significantly when the effects of *R. glabra* are reduced.

In January, 1975, a large, perfect-flowered clone (Fig. 1) was selected in the Pinckney Recreational Area about 12 miles west of Ann Arbor, Michigan. The clone is located in a juniper savannah on a west-facing slope of 7°. The species composition of the area corresponds to the perennial grass stage of succession outlined by Beckwith (1954).

A 6 x 6 m section of the clone was marked off, and on April 12, 1975, 680 grams of urea (46:0:0) were scattered. From early May when the first leaves appeared to mid-July, plants in a 23 x 2 m transect from the north edge to the south edge of the clone were defoliated. Six meters of this transect overlapped with the high nitrogen area. Thus, a control area, a defoliated area, a high nitrogen area, and a defoliated-high nitrogen area were

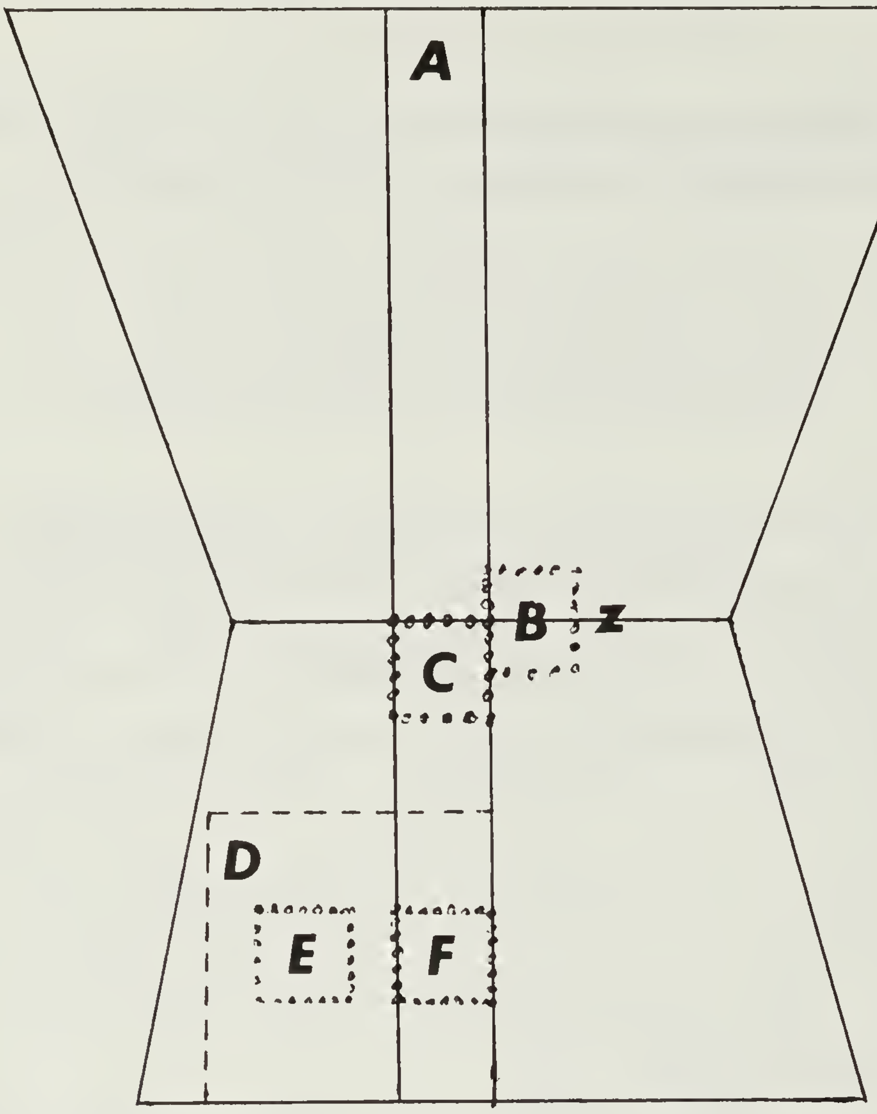

Fig. 1. General shape of the clone. A. Defoliated 2 m transect. B. Clone control sample plot. C. Defoliated sample plot. D. 6 × 6 m high nitrogen area. E. High nitrogen sample plot. F. Defoliated-high nitrogen sample plot. Z. Site of soil sample for seed germination experiments.

established within the clone. Within each of these areas a 2 x 2 m sample plot was established. The sample plots had an estimated *Rhus glabra* cover of 80% or more the previous year. Species composition and abundance-cover were recorded every week from the end of May to July 21 and on August 10, September 4, and September 11, using the relevé method (Benninghoff, 1966). In addition, flowering and fruit set of each species in the sample plots were noted.

At the time of clone selection, a soil sample was taken from a central portion of the clone. The litter was removed, and the top four inches of soil were collected. In the laboratory, the remaining debris and visible roots were removed. Two-thirds of the soil was placed in 32 four-inch pots to a depth of two inches on top of a mixture of greenhouse soil and sand. The pots were placed in a greenhouse at the Matthaei Botanical Gardens of the University of Michigan and watered when dry. Seedlings were identified when possible and harvested. The experiment was terminated after 40 days. From the remaining third of the soil, seeds were extracted in a variety of ways, some separated by flotation, some by examination under a dissecting scope, and others by winnowing. They were identified when possible and placed in petri dishes with two pieces of damp filter paper. The petri dishes were kept in the dark at 18°C. Germination was checked daily, and distilled water was added when necessary to restore moisture to the filter paper. All the seeds were removed upon germination.

SEED GERMINATION EXPERIMENTS: In the pots, 178 seedlings developed. These included several members of the Gramineae, *Trifolium* spp., *Melilotus* spp., *Medicago* spp., *Rhus glabra, Daucus carota, Potentilla* spp., and others. Germination of seeds extracted from the soil under the sumac clone presented problems. By no means did I isolate all the seeds in the soil. Furthermore, identification of seeds was difficult. Most identifications were made by comparisons with seeds collected from plants near the clone. I germinated in petri dishes seeds from various grasses, *Lespedeza* spp., *Verbascum thapsis, Oenothera* sp., *Melilotus* spp., and *Daucus carota.* In addition, I found seeds of *Rhus glabra* and *Prunus* sp. but could not germinate them.

SAMPLE PLOTS: The results of the field manipulations are summarized in tabular form below. No legumes grew in the control plot, but each treatment plot contained two species of legumes. (*Medicago sativa* and *Melilotus alba* grew in the defoliated plot; *Trifolium pratense* and *Vicia villosa* grew in both the high nitrogen and defoliated-high nitrogen plots). In the control plot, no new species appeared after the sumac leaves expanded fully (about June 13). In the defoliated plot, six new species appeared after June 13, and two new species appeared in both the high nitrogen and defoliated-high nitrogen plots. In all plots except the control, the abundance-cover values increased until mid-August. In the control plot, the abundance-cover value attained a maximum on June 6.

TABLE 1. Results of field manipulations designed to test allelopathy in a *Rhus glabra* clone.

		Number of Species		Number of Species in Common			
Sample Plots	Total	With Flowers	With Fruits	Control	Defol.	High Nit.	High Nit.
Control	5	3	2	–	5	5	5
Defoliated	14	11	10	5	–	8	11
High Nitrogen	15	11	8	5	8	–	12
Defoliated-High Nitrogen	18	12	9	5	11	12	–

Rhus glabra may release allelopathic compounds into the soil through leachates from aboveground parts (Tukey, 1966, 1969), by exudation from roots (Rovira, 1969), and by decomposition of plant materials (see Rice, 1974, for review). The germination experiment with seeds extracted from soil in the clone shows that many species are represented in the soil. Furthermore, many of these seeds are viable and will germinate when removed from the influence of Smooth Sumac. Many of the species that germinated in pots did not grow in the control plot but did grow in one or more of the treatment plots.

The number of species in the three treatment plots was significantly higher than in the control plot ($p < .01$). This result is due partially to the presence of legumes in the experimental plots and continued recruitment of species throughout the summer. The effects of direct sunlight alone cannot account for this increase in the number of species. The high nitrogen plot, which had the same amount of shade as the clone control plot, contained about as many species as the defoliated plots. The addition of nitrogen counteracts one possible effect of allelopathy, a low level of available nitrogen. Defoliation eliminates one of the ways in which *R. glabra* may release toxic compounds into the soil. When each of these factors is removed from the environment, the number of species within the clone increases. Consequently, these results are consonant with the idea that *Rhus glabra* chemically depresses the number of species occurring in its clone.

I would like to thank Edward G. Voss, who helped with identifications; Susan Tyzenhouse, who assisted in field experiments; and Bruce Lazerte, Deborah Rabinowitz, Wm. Wayt Thomas, and James Winsor, who read and criticized the manuscript. William Benninghoff and Eric Steiner made facilities of the Matthaei Botanical Gardens available. I am especially indebted to George Estabrook, whose comments and criticisms were helpful in every phase of this project.

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THE IMPACT OF SNOWMOBILING ON GROUND LAYER VEGETATION NEAR SAGE LAKE, OGEMAW COUNTY, MICHIGAN

Richard H. Baetsen
4304 North St.
Akron, Michigan 48701

In an age of technical achievement we are constantly faced with solving problems that did not exist a few years ago. In 1961 a few hundred snowmobiles were manufactured, but by 1971, 500,000 were being produced annually (Gamble, 1971). In Michigan alone there were 392,108 registered snowmobiles in 1974 (Opolka & Patrick, 1975). Ecologists were quick to begin studies to establish the ecological impact of these machines (Wanek, 1971; Whittaker & Wentworth, 1971). A search of the literature indicates that there are varying results as to the impact of snowmobiles on vegetation (Wanek, 1971, 1972, 1973; Whittaker & Wentworth, 1971; Masyk, 1973). The field conditions which have been studied do not seem to show the actual situation found under established snowmobile trails. The primary objective of my study was to investigate the ecological impact of five years of snowmobile use on forest ground layer vegetation.

Voucher specimens have been deposited in the herbarium of the Biology Department of Lake Superior State College, Sault Ste. Marie, Mich. Nomenclature follows Gleason and Cronquist (1963).

STUDY AREA

The analyzed snowmobile trail is found on an 80 acre tract located in a portion of the SW¼ of Section 26, T23N, R4E, Ogemaw County, Mich. (Fig. 1). This particular trail was chosen for the following reasons: (1) The trail has "average" or slightly below average usage. (2) It is used only by snowmobiles (use by all-terrain vehicles or trail-bikes has not been noted during the five-year period of trail use). (3) The trail has a circular turn-around with no other access. This creates a two-level usage by snowmobiles. A double usage impact occurs as snowmobiles enter and exit the trail and a single usage impact occurs on the turn-around. The trail lies in a large-toothed aspen (*Populus grandidentata*) dominated stand. The soil has a high sand content with relatively good drainage. With the advent of the snowmobile, local resort people established trails through the forest stand. There is no evidence that any vegetation was cut to establish the trail. This trail is one of many found in the Sage Lake resort area. It is a well-established, but unmarked trail. It is not connected to a major trail nor does it have direct lake access.

MATERIALS AND METHODS

Field work began in late March 1974. The trail was located and marked when there was still snow. The exact trail location could then be found later

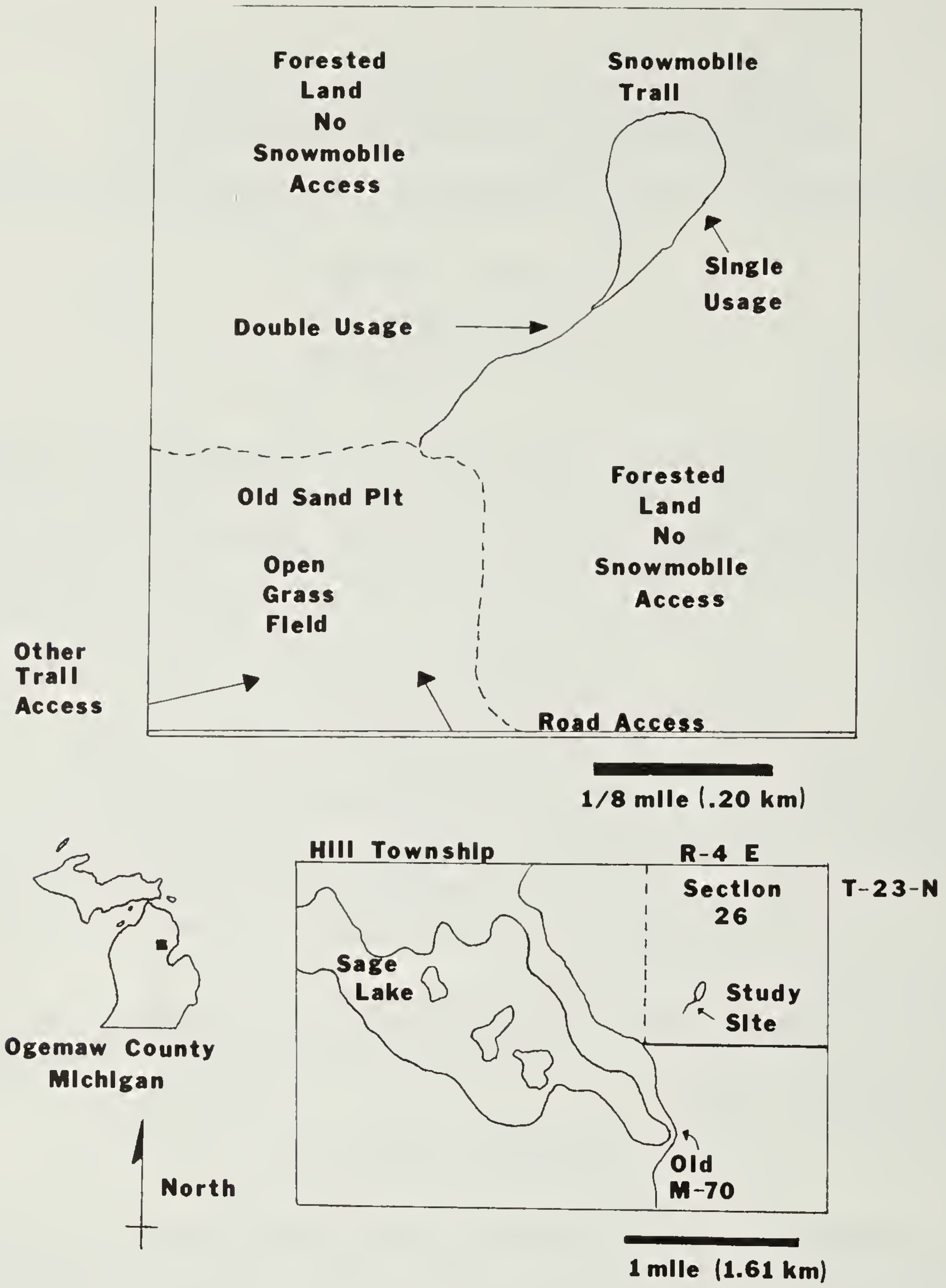
Forested Land No Snowmobile Access
Snowmobile Trail
Single Usage
Double Usage
Old Sand Pit
Open Grass Field
Forested Land No Snowmobile Access
Other Trail Access
Road Access
1/8 mile (.20 km)
Ogemaw County Michigan
North
Hill Township
R-4 E
Section 26
T-23-N
Sage Lake
Study Site
Old M-70
1 mile (1.61 km)

Fig. 1. Location of the snowmobile trail studied. Trail has a circular turn-around creating two snowmobile usage levels.

for studying summer vegetational growth. Starting July 4, 1974, data were collected along a series of belt transects 18 feet (5.49 m) long and six inches (0.15 m) wide placed perpendicular to the trail. Of a total of 36 quadrats on each transect, 18 were located to the right and 18 to the left of the trail center; of these, eight were located on the trail and 28 off the trail. List quadrats were used to collect presence data. A species needed to be represented only by a single plant in order to be counted present in a quadrat (Cain & Castro, 1959). The first transect was established randomly; the rest were placed at five foot intervals. Seventy-five transects were established on each of the two usage level portions of the snowmobile trail.

During the winter of 1974-1975, four temperature stations were established (two under the snowmobile trail and two off the trail under undisturbed snow). The temperature probes were located directly below the litter layer. The litter layer was approximately one inch thick off the trail; on the trail it was always less. Fifteen temperature readings were taken at various times during the day and night at each station (mostly on weekends) when temperatures were above 5°F (−15°C), the lower limit of the TRI-R electronic thermometer used.

Although data were collected from 36 quadrats per belt transect, for statistical tests eight quadrats from the trail and eight to the right and left were used. Preliminary analysis indicated that it was not necessary to use all the off-the-trail quadrats for statistical tests. To determine the significance of the difference between on and off-the-trail frequencies 2 x 2 contingency tables were used for chi-square calculations. To determine whether a significant difference in frequencies occurred between the two usage levels, a test of interaction (analysis in the p scale: a 2 x 2 table) was used (Snedecor & Cochran, 1967).

RESULTS

The average air temperature for the 15 days on which readings were taken was 23°F (−5°C) with a maximum temperature of 50°F (+10°C) and a minimum of 6.8°F (−14°C). Litter layer temperatures under compacted snow fluctuate more and are colder than those found under uncompacted snow. The coldest temperature recorded under uncompacted snow was 30.2°F (−1.0°C) and under compacted snow it was 14.9°F (−9.5°C). The maximum difference was 15.3°F (8.5°C).

The tabulated vegetation data (Table 1) suggest that snowmobile travel on an established trail does have an important impact on the ground layer vegetation. The frequency differences between species on and off the trail can be seen in Table 1.

Considering the single usage area, several species (wild aster, *Aster macrophyllus;* starflower, *Trientalis borealis;* red maple, *Acer rubrum;* and an unidentified grass) had small frequency decreases on the trail of 0.7% to 2.0%. Flowering wintergreen *(Polygala paucifolia)* decreased 3.7%. Bracken fern *(Pteridium aquilinum)* and wintergreen *(Gaultheria procumbens)* had greater reductions of 15.4% (Fig. 2) and 12.8% (Fig. 3), respectively.

When data are examined for the double usage area, one can see greater reductions in presence where travel is increased, except in the case of speargrass *(Poa annua),* which increased by 19.6%. This was the only species that could be statistically tested for significance that increased in occurrence on the trail. The others ranged from a 5.1% reduction in *Trientalis borealis* to a reduction of 26.4% in *Pteridium aquilinum* (Fig. 2). Others that had significant reductions were *Gaultheria procumbens*, 21.4% (Fig. 3); *Polygala paucifolia,* 14.9%; *Acer rubrum,* 14.2%; the unknown grass, 12.0%; and wild lily of the valley *(Maianthemum canadense),* 6.2%.

When using the interaction test to compare the statistical differences between the two usage levels, one can see (Table 1, last column) that a significant difference was found in all but two species that could be tested. This indicates that double usage had a more definite effect on plant life than single usage.

TABLE 1. The effects of two snowmobile usage levels on the frequency (percentage) of quadrats containing various ground layer plant species.

Species	Single Usage Frequency Under Trail	Single Usage Frequency Off Trail	Single Usage Difference	Double Usage Frequency Under Trail	Double Usage Frequency Off Trail	Double Usage Difference	Interaction Test
Pteridium aquilinum	13.8	29.2	−15.4**	5.6	32.0	−26.4**	Sig. .01
Gaultheria procumbens	49.2	62.0	−12.8**	34.2	55.6	−21.4**	Sig. .05
Polygala paucifolia	1.2	4.9	− 3.7**	6.1	21.0	−14.9**	Sig. .01
Acer rubrum	13.5	15.5	− 2.0	16.8	31.0	−14.2**	Sig. .01
Unknown Grass	3.2	5.2	− 2.0*	2.4	14.4	−12.0**	Sig. .01
Maianthemum canadense	++			10.8	17.0	− 6.2**	No Test
Trientalis borealis	.2	1.0	− .8*	2.5	7.6	− 5.1**	Sig. .01
Aster macrophyllus	.3	1.0	− .7	8.5	12.3	− 3.8*	Not Sig.
Vaccinium angustifolium				.8	3.5	− 2.7**	No Test
Solidago sp.				2.5	4.0	− 1.5	No Test
Rubus occidentalis	2.5	2.4	+ .1	5.6	7.0	− 1.4	Not Sig.
Fragaria virginiana				15.0	14.5	+ .5	No Test
Poa annua				28.8	9.2	+19.6**	No Test

*Significance at .05 level of probability.
**Significance at .01 level of probability.
++Blank spaces indicates insufficient data to test statistically.

DISCUSSION

After five years of snowmobile traffic the ground layer species found on an established trail showed varied reactions. The data suggest a direct correlation between the intensity of traffic and the decrease or increase of species occurrence.

The impact of snowmobile usage upon plant vegetation can not be easily attributed to any one factor. The most obvious factor is direct physical damage. Use of trails too early or late in the season when snowcover is inadequate or removal of all snow by machine sliding or spinning can cause destruction to vegetation (Masyk, 1973). Snow removal exposes the soil layer to the direct harshness of the winter environment. A foot or more of snow may be sufficient to protect some ground layer vegetation from damage after only one or two snowmobile traverses, although it has been shown that in

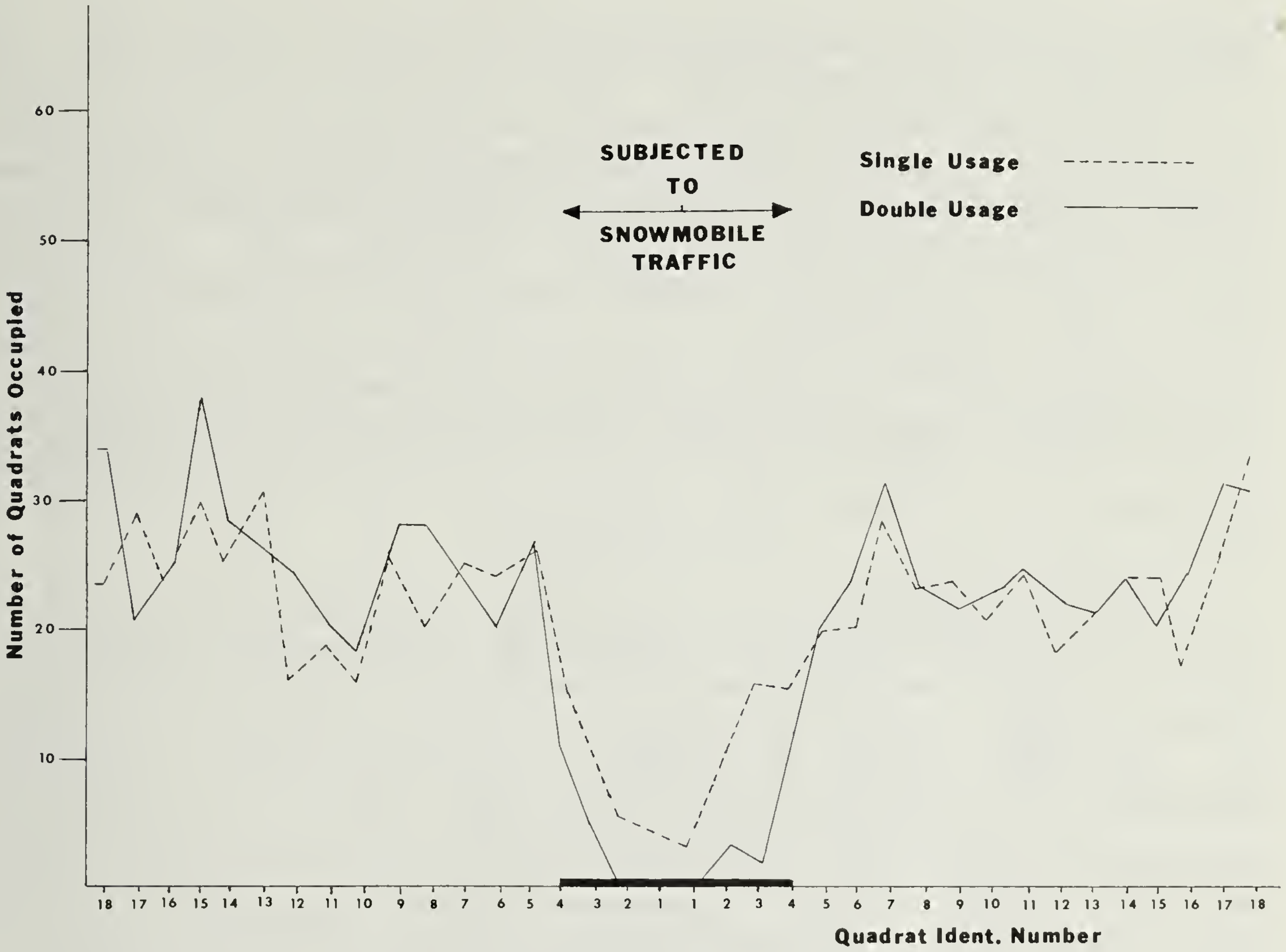

Fig. 2. Number of quadrats that *Pteridium aquilinum* occupied (75 being the total number of quadrats sampled for each usage level) in relationship to snowmobile traffic.

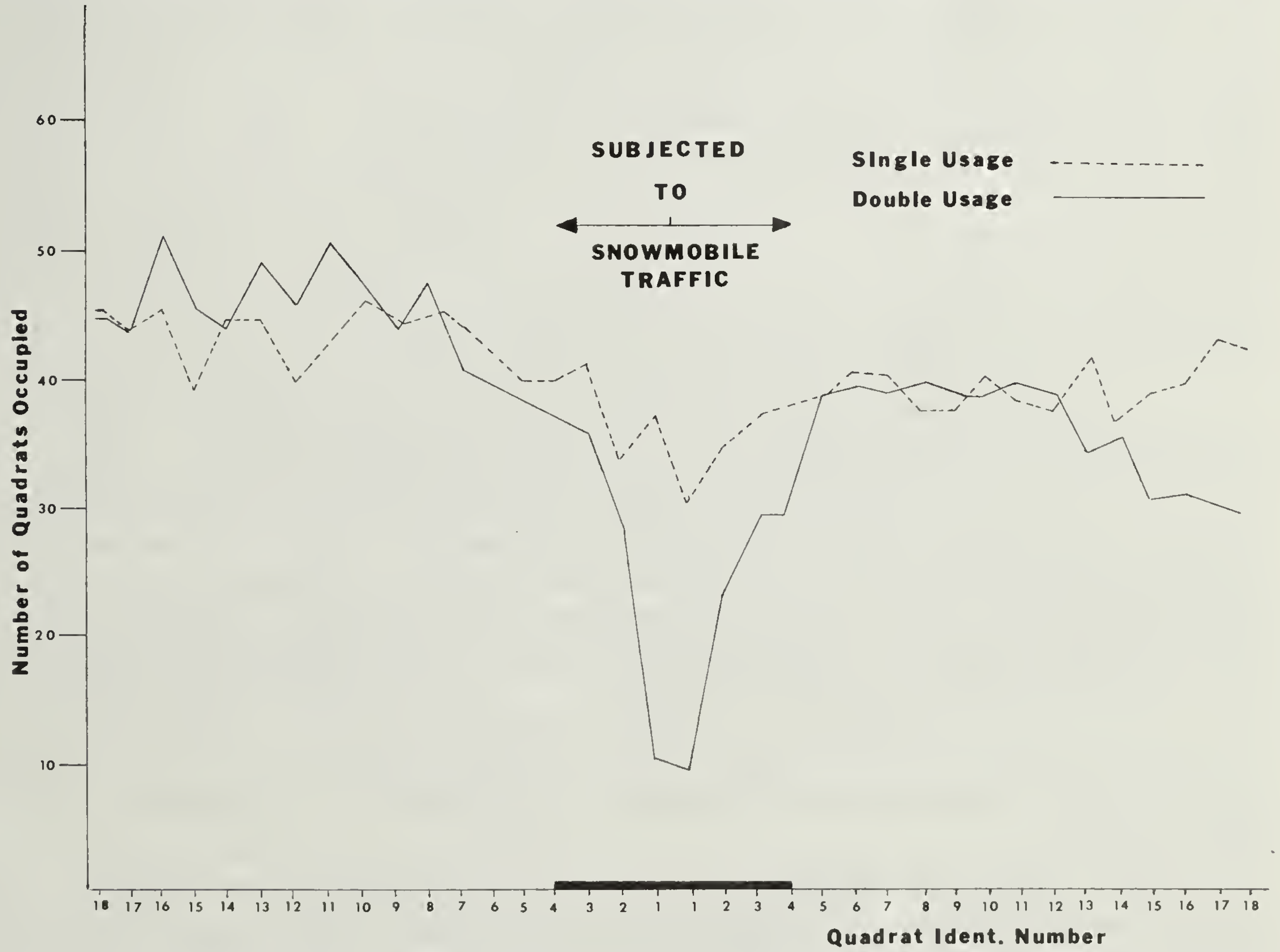

Fig. 3. Number of quadrats that *Gaultheria procumbens* occupied (75 being the total number of quadrats sampled for each usage level) in relationship to snowmobile traffic.

nurseries and conifer plantations, significant damage can occur after one snowmobile traverse (Wanek, 1971).

A factor that may affect the growth and reproduction of plants is light. The compacted icy covering left by snowmobile trails in the spring must have an immense effect on survival. The delay of a number of the plant's functions, including photosynthesis, could put stress on the plant. The result of such stress might be stunted growth, reduced flowering and reproduction, or death (Levitt, 1972). Shading may influence what species are successful. Data indicate that *Pteridium aquilinum* is very sensitive to snowmobile travel. It shows a 26.4% reduction under the double usage trail, whereas *Poa annua* had an increase of 19.6% under the same trail. The increase could possibly be due to the removal of *Pteridium.* This increased light might release an otherwise shade restricted grass.

The most complicated factor to be considered is the compaction of the snow under a snowmobile trail. During the winter months, many forest ground layer species are protected by a mulch of leaf litter and snow which provides a highly modified environment for the plant (Angelo *et al.*, 1939). The snowmobile reduces the thermal insulation value of the snow by compacting it. McFadden (1972) stated that in lower snow layers, uncompacted snow density was 0.22 g/cc compared to 0.47 g/cc under snowmobile activity. Thermal conductivity has been calculated to be 11.7 times greater under a compacted snowmobile trail than under "free snow" (Masyk, 1973). Due to the increased thermal conductivity of compacted snow, the litter layer temperature fluctuates more with the changes in the ambient air temperature, thus lower temperatures are found under compacted snow than under uncompacted snow. One measurement showed a 15.3°F (8.5°C) colder temperature under the trail compared with that under uncompacted snow; this compares well with previous studies (Wanek, 1971, 1972, 1973). The melting of compacted snow is said to lag significantly behind that of uncompacted snow—1.6 to 1.9 times slower (Masyk, 1973; Wanek, 1973). Such a lag is supported by my own observations during the spring of 1974 and 1975. The soil temperature under compacted snow also remains cooler in the spring. An equilibrium in soil temperature might take up to 10 to 14 days to be reached (Wanek, 1971). This lag in cold temperatures suggests a shortening of the growing season of up to nearly a month (Masyk, 1973). This shortened growing season could be critical in northern snowbelt states where the growing season is already temperature limited. This delay would have crucial importance to some forest perennials that are spring ephemerals. These species depend on an early emergence for their survival. They survive by having large underground storage organs. Risser and Cottam (1967) found that the development and growth of several spring ephemerals was retarded at temperatures of 32°F (0°C) and below. A temperature of 14.9°F (-9.5°C) suggests that snowmobile travel could be detrimental to the growth of this type of plant.

The extent of damage to plants is dependent on critical low temperatures, ambient air temperature, soil moisture and type, litter and humus makeup and amount, and the individual plant condition (Levitt, 1972).

Thus, it has been established that snowmobiles do have an ecological impact on plants, varying with traffic. Colder temperatures caused by snow compaction and actual physical snowmobile contact are suggested as responsible for changes in the plant composition found on the trail, as compared with that off the trail. This indicates that careful planning might be necessary for snowmobile use in agricultural areas and in natural areas. The possible exclusion of snowmobiles might be necessary to maintain natural areas.

I would like to thank the following people for assistance in this project: Bernard and Robert Baetsen, Dr. David Behmer, Dr. Richard Furr, Bonnie Heuvelhorst, and Dr. Bryce Smith.

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ADDITIONS TO THE FLORA OF ALLEGAN COUNTY

Steven G. Bruggers[1] and Paul Van Faasen
Biology Department
Hope College, Holland, Michigan 49423

In addition to providing an authoritative reference, the recent publication of a flora as good and as complete as Part I of Voss's *Michigan Flora* spurs those who work in the "provinces" to fill in blank spots in the distribution maps. Primarily as parts of other investigations, we collected three gymnosperm and 29 monocot species previously unreported for Allegan County. They are presented below without locality data. Voucher specimens with complete data are deposited in the Hope College Herbarium (HCHM). Several of these records are expected extensions of distributions. Their absence from county records reflects the fact that few people have worked in that county. Many of the records result from the presence of the floristically rich Miner Lake Bog and document the location of a specialized habitat and its unique inhabitants.

Of special interest are collections of *Thuja occidentalis* near its southern limit in Michigan; the southernmost Michigan collection of *Pinus resinosa;* the first western Michigan collection of *Carex chordorrhiza;* the first collection of *Arethusa bulbosa* from a Lake Michigan shoreline county; and a southern collection of *Malaxis unifolia.*

Without the assistance of David Van Appledorn several of the orchids would still be unreported. One collection by Carol Maat and one by Gary Morton are also acknowledged.

PINACEAE
Larix laricina (DuRoi) K. Koch
Pinus resinosa Ait.
Thuja occidentalis L.
TYPHACEAE
Typha latifolia L.
JUNCAGINACEAE
Triglochin maritimum L.
SPARGANIACEAE
Sparganium chlorocarpum Rydb.
GRAMINEAE
Phalaris arundinacea L.
Spartina pectinata Link
CYPERACEAE
Carex atlantica Bailey
Carex cephalophora Willd.
Carex chordorrhiza L.f.
Carex disperma Dewey
Carex plantaginea Lam.
Carex rostrata Stokes
Cyperus diandrus Torrey
Eleocharis intermedia Schultes
Eriophorum gracile W.J.D. Koch
Eriophorum virginicum L.
Rhynchospora alba (L.) Vahl
ARACEAE
Symplocarpus foetidus (L.) Nutt.
LILIACEAE
Hemerocallis fulva (L.) L.
Lilium michiganense Farw.
Smilax ecirrata (Kunth) S. Watson
Trillium flexipes Raf.
Trillium cernuum L.
IRIDACEAE
Sisyrinchium angustifolium Miller
ORCHIDACEAE
Arethusa bulbosa L.
Cypripedium acaule Ait.
Habenaria clavellata (Michx.) Spreng.
Habenaria flava (L.) Spreng.
Malaxis unifolia Michx.
Orchis spectabilis L.

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LIFE-FORMS IN THE MICHIGAN FLORA

John W. Thieret
Department of Biological Sciences
Northern Kentucky University, Highland Heights 41076

This paper presents a life-form analysis of the native spermatophytes of Michigan—about 1600 species. Separate analyses are given for the native floras of Berrien County and Keweenaw County (excluding Isle Royale). The life-form classification I use is that of Raunkiaer (1934), based on the position of the perennating buds or meristems during the unfavorable season.

Few life-form studies have been done in North America. Especially pertinent to my Michigan work are those for Kentucky (Gibson, 1963), Indiana (McDonald, 1937), Illinois (Hansen, 1952), Iowa (McDonald, 1937), Minnesota (Thieret, 1967), and southern District of Mackenzie (Thieret, 1963). Cooper's (1961) work in southeastern Michigan attempts to correlate life-form and microclimate. If Raunkiaer's system is to be evaluated for North America, many additional life-form analyses of the continent's floras are needed. The present paper is a contribution toward this end.

CLASSIFICATION OF LIFE-FORMS

Raunkiaer's life-form system, independent of the usual taxonomic hierarchy, has five main classes:

Class I. PHANEROPHYTES (Ph) bear their perennating buds at least 25 centimeters above the soil surface; the buds of phanerophytes are more exposed to the ambient atmospheric environment than those of other life-forms. The class is subdivided by height into *mega-mesophanerophytes,* over 8 meters tall; *microphanerophytes,* 2 to 8 meters tall; and *nanophanerophytes,* 25 centimeters to 2 meters tall. Phanerophytes are predominant in humid tropical floras and tend to decrease in proportion to other life-forms in regions with climates less favorable to plant growth.

Class II. CHAMAEPHYTES (Ch) bear their buds above the soil surface but lower than 25 centimeters; the buds are less exposed to the ambient atmospheric environment than those of phanerophytes. The Ch percentage in floras increases with increasingly high altitude or latitude or both. An especially high Ch percentage characterizes arctic and alpine regions.

Class III. HEMICRYPTOPHYTES (H) bear their buds in the surface layer of the soil; the buds are even more protected than those of chamaephytes. This class is dominant in temperate floras, often making up half or more of the species in grasslands and deciduous forests. Hemicryptophytes are also common in boreal forest and in tundra. Three subtypes are distinguished: *protohemicryptophytes, semi-rosette hemicryptophytes,* and *rosette hemicryptophytes.* The first of these has cauline leaves only, the second has both cauline and basal leaves, and the third has all its leaves in a basal rosette.

Class IV. CRYPTOPHYTES (Cr) bear their buds below the surface of the soil, or in water, or in the substratum under the water; the buds are better protected than those of hemicryptophytes. Cryptophytes are of two subtypes: *geophytes* and *helo-hydrophytes.* Geophytes are land plants whose perennating structures are bulbs, corms, rhizomes, stem tubers, or root tubers; a few are root parasites. Helo-hydrophytes are the so-called "marsh" and "aquatic" plants. Cryptophytes are not characteristic of any particular kind of climate although they are absent or rare in the high arctic.

Class V. THEROPHYTES (Th) are annual plants, which survive the unfavorable season as seeds, structures considered by some to be the ultimate in protection of perennating buds (meristems). This class is especially abundant in deserts and in the pioneer weedy communities that develop where native vegetation is disturbed.

LIFE-FORM SPECTRUM AND PHYTOCLIMATE

The "life-form spectrum" of a flora shows the percentage of each of the five life-form classes in that flora. According to Raunkiaer, such a spectrum can be used to define what he called the "phytoclimate" of the region concerned; further, differences in spectra of different regions reflect differences in phytoclimate between these regions.

Four types of phytoclimate were recognized by Raunkiaer: phanerophytic, chamaephytic, hemicryptophytic, and therophytic (he did not recognize a cryptophytic phytoclimate). In his development of the concept of phytoclimate and life-form spectra, Raunkiaer devised the "Normal Spectrum" (Ph 46, Ch 9, H 26, Cr 6, Th 13), which is an estimate, based on 1000 randomly-selected species of the world flora, of the percentage of each of the five life-form classes in that flora. Every *regional* life-form spectrum has, according to Raunkiaer, at least one life-form class with a percentage "significantly" higher than that of the Normal; it is this class that defines the phytoclimate of the region. For example, the life-form spectrum of Minnesota (Thieret, 1967) is Ph 13, Ch 3, H 49, Cr 22, Th 13. The H percentage is about double that of the Normal, and so Raunkiaer would characterize Minnesota's phytoclimate as hemicryptophytic.

METHODS

A first step in my life-form study was to determine what native species occur in Michigan. The state's monocots and gymnosperms are well accounted for by Voss (1972). I drew up a checklist of Michigan dicots through study of standard manuals (especially Gleason & Cronquist, 1963) various floristic lists, and pertinent monographs, and through aid unstintingly given by Dr. Voss. Berrien County plants are accounted for in Swink (1974); those of Keweenaw County, in Wells and Thompson (1974). For each Michigan spermatophyte, I determined the life-form through field, herbarium, and literature studies.

The decision as to whether certain species are actually native in Michigan was difficult or even impossible. In cases of uncertainty, I in general excluded these species from consideration. The number of such species was so small, however, that their exclusion had essentially no influence on the life-form spectra involved.

RESULTS

Life-form data for Michigan as a whole, for Berrien County, and for Keweenaw County are given in Table 1. The Normal Spectrum, the life-form spectrum for Michigan, and the spectra for selected other areas in North America are given in Table 2.

TABLE 1. Life-form data for Michigan, Berrien County, and Keweenaw County. Figures represent percentages and are based on native species only.

	Michigan 1608 species		Berrien County 1030 species		Keweenaw County 667 species	
Phanerophytes						
Mega-mesophanerophytes	4.7		5.9		4.6	
Microphanerophytes	5.3		5.5		6.0	
Nanophanerophytes	4.2		3.7		6.9	
Total phanerophytes		14.2		15.1		17.5
Chamaephytes		2.2		1.9		2.7
Hemicryptophytes						
Protohemicryptophytes	15.2		18.0		10.2	
Semi-rosette hemicryptophytes	32.7		28.7		34.0	
Rosette hemicryptophytes	3.7		3.7		5.1	
Total hemicryptophytes		51.6		50.4		49.3
Cryptophytes						
Helo-hydrophytes	7.8		6.3		8.7	
Geophytes						
Rhizome geophytes	9.7		9.2		11.8	
Stem-tuber geophytes	1.8		2.3		2.0	
Root-tuber geophytes	1.6		1.9		2.0	
Bulb geophytes	0.6		0.9		0.4	
Root-bud geophytes	0.4		0.5		0.4	
Root parasites	0.2		0.2		0.1	
Total cryptophytes		22.1		21.3		25.5
Therophytes		9.2		11.2		4.8

TABLE 2. The Normal Spectrum, the life-form spectrum for Michigan, and the spectra for selected other areas in North America.

	Ph	Ch	H	Cr	Th
Normal Spectrum (Raunkiaer, 1934)	46.0	9.0	26.0	6.0	13.0
Michigan	14.2	2.2	51.6	22.1	9.2
Kentucky (Gibson, 1963)	17.6	1.4	52.6	16.6	11.8
Indiana (McDonald, 1937)	15.3	1.7	50.3	19.6	13.0
Illinois (Hansen, 1952)	15.5	1.6	50.2	19.8	12.9
Iowa (McDonald, 1937)	14.8	1.0	48.6	20.9	14.2
Minnesota (Thieret, 1967)	13.0	3.0	49.0	22.0	13.0
Southern District of Mackenzie (Thieret, 1963)	11.9	7.7	55.7	18.7	5.1

DISCUSSION

Michigan, with a land area of 56,817 square miles, lies within the Deciduous Forest Formation of eastern North America (Braun, 1950); the lower half of the Lower Peninsula is in Braun's Beech-Maple Forest Region; the upper half of the Lower Peninsula and all of the Upper Peninsula are in her Hemlock-White Pine-Northern Hardwoods Region.

A discussion of Michigan life-forms may be introduced by the following quotation from Raunkiaer (1934: 133).

> In the northern cold temperate and cold zones as we gradually go towards the north we find that the biological [*i.e.*, life-form] spectrum of the vegetation changes in a very definite manner. The Phanerophytes and the Therophytes decrease and finally disappear. The Cryptophytes, too, which are well represented throughout most of the region, disappear entirely from the hostile regions of the extreme north. The percentage of Hemicryptophytes keeps fairly constant, being approximately double the percentage found in the whole world. The Chamaephyte percentage on the other hand gradually increases toward the north; in the southern parts of the region it is a long way below the Normal Spectrum, but after reaching this figure it soon doubles it. Ultimately the Chamaephyte percentage becomes three times or more that of the Normal Spectrum. All these changes follow the same series everywhere, whichever meridian we follow.

The life-form spectrum for Michigan indicates that the phytoclimate of the state is hemicryptophytic. The Michigan H percentage is about double that of the Normal Spectrum. The Ph, Ch, and Th percentages are *below* those of the Normal Spectrum.

Comparison of the Michigan spectrum can logically be made with the spectra of Minnesota, Indiana, and Kentucky. Hardly a surprising datum is that the Michigan spectrum is most closely similar to that of Minnesota. The somewhat lower Ch percentage in Michigan is an unexpected difference. Michigan and Minnesota have about the same number of Ch species, but the *total number* of species known in Michigan is greater—perhaps the result of more thorough collecting of the flora there.

The Ph percentage in Michigan is lower than that of Indiana, immediately to the south, and lower yet than that of the still-farther south Kentucky, in line with Raunkiaer's postulate. In addition, the Michigan Ph flora contains a *larger* proportion of phanerophytes of *smaller* stature than either Indiana or Kentucky. Michigan phanerophytes are all woody plants, mostly trees and shrubs but also a few vines.

The Ch percentages in Kentucky, Indiana, and Michigan show a gradual increase from south to north, also in line with Raunkiaer. An interesting point is that Michigan has fewer chamaephytes than Indiana; the higher Ch percentage in Michigan is derived mainly through its smaller *total* native flora. The Michigan families with the most chamaephytes are Ericaceae and Caryophyllaceae.

The H percentage in Michigan, as previously discussed, is essentially equal to the percentages of Kentucky and Indiana (and also of Illinois and Minnesota)—about double the Normal.

The Michigan Cr percentage is somewhat greater than that of Indiana and Kentucky (and is about equal to that of Minnesota). This can almost certainly be ascribed in large part to the richer aquatic and marsh flora found in Michigan.

The Th percentage of Michigan is lower than that of Indiana and Kentucky. Such a decrease is in harmony with the postulates of Raunkiaer.

A north-south distance of about 350 miles separates the counties of Berrien–southwesternmost in Michigan–and Keweenaw–northernmost in the state. These counties are both small:–Berrien, with a land area of 580 square miles, and Keweenaw (excluding Isle Royale), 334. The *higher* Ph percentage for Keweenaw County is somewhat unexpected and suggests that factors other than latitude alone may be involved. It is conceivable that local conditions on the distal portion of the Keweenaw Peninsula–site of Keweenaw County (excluding Isle Royale)–may favor phanerophytes over other life-forms. Conceivable also is that the seemingly high Ph percentage is an artifact created by the vagaries of collecting of the county's flora, which almost certainly would cover the woody plants more thoroughly than herbaceous ones and thus by itself would create a higher Ph representation. (See, below, "Problems in life-form analysis.")

The Ch and H percentages in the two counties are within the realm of "expected" and harmonize with Raunkiaer's postulates. The Th percentage, however, is surprisingly low in Keweenaw County. One would expect it–in line with Raunkiaer–to be lower than in Berrien County but perhaps not so low as it is. Again, here, local conditions and the vagaries of collecting may be responsible.

PROBLEMS IN LIFE-FORM ANALYSIS

The student of life-forms faces several problems in his work. Among these are (1) the species concept followed during the drawing up of the species list for the region and (2) the state of knowledge of the flora. The first of these may in certain cases be a more serious problem than the second.

For the assembler of a list of Michigan dicots the problem of what constitutes a species is of especial and notorious significance in *Crataegus* and *Rubus*. Does one accept a narrow or a broad concept of species in these genera? Because the number of species ascribed to *Crataegus* and *Rubus* is considerably larger if one is a splitter, the total number of species of dicots in Michigan becomes greater and the final figures for the life-form spectrum will differ from those figures as calculated by a lumper. For example, I included only 13 "species" of *Crataegus* in my calculations, following the species concept of Gleason and Cronquist (1963). But perhaps 100 "species" of this genus have been reported from Michigan. A recalculation of the Michigan life-form spectrum using 100 "species" of *Crataegus* instead of 13 makes the following difference.

13 "species" of *Crataegus:* Ph 14.2, Ch 2.2, H 51.6, Cr 22.1, Th 9.2.
100 "species" of *Crataegus:* Ph 18.8, Ch 2.1, H 50.0, Cr 21.2, Th 8.8.

While there is still no doubt that the recalculated spectrum is from a region of hemicryptophytic phytoclimate, the Ph percentage is a good deal higher than in the 13-species spectrum. Obviously, the breadth of species concept does indeed make a difference. Obviously, too, the last word on the Michigan Ph percentage has yet to be said. And it is also obvious that, when comparing spectra of different regions, one must take care that *Crataegus, Rubus,* and other "problem" genera are interpreted similarly in these regions. (As with *Crataegus,* I follow Gleason and Cronquist [1963] also for *Rubus.*) The study of life-forms is dependent upon sound taxonomy.

The above example using *Crataegus* shows change wrought in a spectrum when the additional species are all of one life-form. But what happens when, as knowledge of a flora increases through the collection of species "new" to that flora, the additional species represent all life forms (as is almost always the case)? For example, in an unpublished study I found the life-form spectrum of the islands in Lake Erie to be

Ph 17.8, Ch 1.3, H 42.5, Cr 25.4, Th 12.7

when calculated from the "accepted" flora of the islands, *i.e.,* the flora for whose 530 native species there are available voucher specimens. Then I recalculated the spectrum, using as species "new" to the flora the 100 species that have been recorded for the islands but for which there are apparently no extant vouchers. Even when the species base was increased by one-fifth, there was little difference in the spectrum, which was

Ph 17.7, Ch 1.4, H 44.9, Cr 23.3, Th 12.4.

The differences were largely in herbaceous life-forms—hemicryptophytes and cryptophytes—rather than in phanerophytes (one can expect the number of herbaceous species added to reasonably well-known floras to exceed the number of woody species added). Nevertheless, there *was* a difference, enough to call into question the value of the recalculated spectrum for purposes of comparison of spectra of different regions. The study of life-forms is dependent upon sound floristic knowledge of the regions concerned.

The significance of small departures from "expected" percentages and of small differences between spectra is a little understood subject. We simply do not know what magnitude a departure or a difference must be to constitute, in life-form terms, a figure that is significant. Perhaps future students of life-forms will establish guidelines on this subject.

There has been a tendency in regional life-form studies in North America to ascribe differences in spectra solely or largely to differences in latitude or altitude. But certainly latitudinal and altitudinal differences are not the only ones that influence life-form spectra. For example, the Erie Islands have a Ph percentage higher than "expected" and H and Cr percentages lower than "expected." I ascribe these departures to the peculiar climatic and edaphic conditions that made the islands "semi-arid." This semi-aridity may well favor more deeply-rooted species (largely the phanerophytes) and exclude some of the more shallowly-rooted ones (hemicryptophytes and cryptophytes). Similarly the seemingly high Ph percentage in Keweenaw County may have less to do with latitude than with local conditions that favor some life-forms over others.

Students of life-forms must make certain that, with their published spectra, it is *clearly* indicated whether the spectra are based on native species or on native plus introduced species. Unless this indication is made—and sometimes it is not—I believe that the value of such spectra for comparative purposes is significantly reduced. It would be good to see more life-form studies of specific habitat types, *e.g.,* bogs, floodplains, and deciduous forests of various types.

SUMMARY

A life-form study, using the Raunkiaer classification, was made of the native seed-plants of Michigan. Three life-form spectra are presented: Michigan—Ph 14.2, Ch 2.2, H 51.6, Cr 22.1, Th 9.2; Berrien County—Ph 15.1, Ch 1.9, H 50.4, Cr 21.3, Th 11.2; and Keweenaw County—Ph 17.5, Ch 2.7, H 49.3, Cr 25.5, Th 4.8. These data indicate that a hemicryptophytic phytoclimate characterizes Michigan and are generally in harmony with Raunkiaer's postulates on the relation between life-form spectra and latitude. Brief discussion is given of some of the problems encountered during life-form analyses.

The work for this paper was done largely at the University of Michigan Biological Station. Much help was received from Dr. Edward G. Voss. My interest in life-forms was originally awakened by Dr. Theodor Just.

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A BOTANICAL INVENTORY OF SANDHILL WOODLOT, INGHAM COUNTY
III. PHENOLOGY STUDY

Darlene M. Frye

Botany Department, Rutgers University
New Brunswick, New Jersey, 08903

A vegetational analysis (Frye, 1976a) and a checklist of vascular plants (Frye, 1976b) of Sandhill Woodlot were previously presented. This paper reports the results of a phenology study conducted April through October 1971 for use in the proposed woodlot management and in subsequent studies comparing local phenological adaptations of species with a wide geographic distribution. These data illustrate the life histories of the selected species growing in central Michigan and can therefore be used for research and teaching and for general wildflower observation and photography.

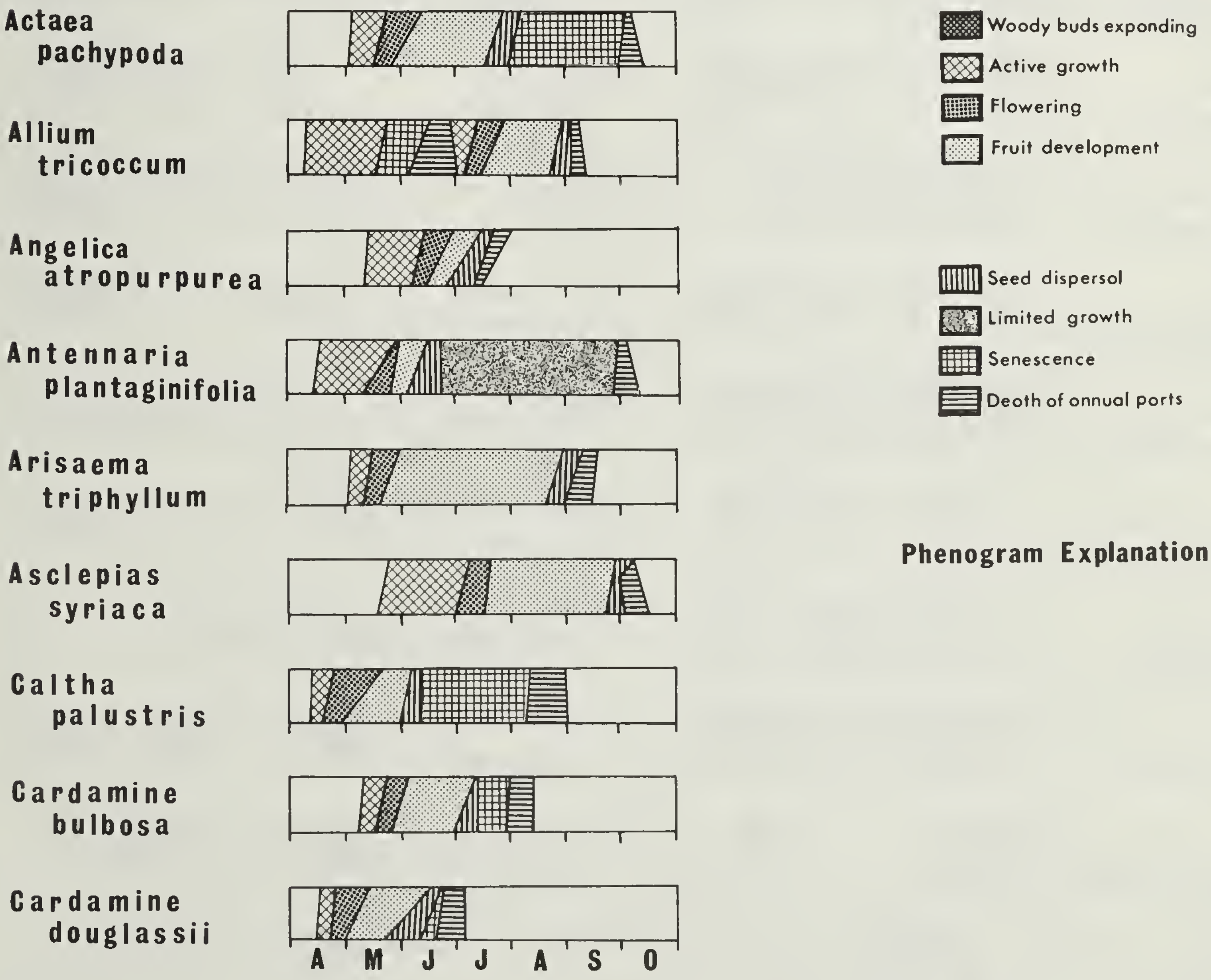
Phenology is the study of relationships between various physical factors of the environment and seasonal changes in growth and development during the life cycle of plants and animals (Newman & Beard, 1962). In plants, these life cycle phases include germination or initation of seasonal growth, leaf development, flowering, fruiting, seed dispersal, senescence, and leaf fall or die back. Though these events are genetically controlled for each species, environmental factors (light, moisture, and temperature) influence the onset of the phases. The onset of a phase and/or the length of its occurrence may vary slightly from year to year corresponding to changes in environmental factors. Taylor (1969) in his Oak Ridge phenology study found as much as a month's difference in the onset of flowering. It would therefore be necessary to conduct a phenology study over a period of several years to insure a more accurate account of the species' life cycles. Jackson (1966) proposed an alternative whereby a study of plants growing in a wide spectrum of environmental conditions over a period of one year would produce comparable results. His technique was used in this study. Individuals were selected from various locations in the central and southern portions of the woodlot where observations were recorded at two day intervals. Expansion of buds, active growth, flowering, fruit development, seed dispersal, limited growth, senescence, and death of annual parts were observed for 18 woody plant species and 45 herbaceous species. These data are summarized in the phenograms which are presented in Table 1 for herbaceous plants and in Table 2 for the woody plants. Slanting stage boundaries in the phenograms indicate overlap of stages and do not necessarily indicate a quantitative measure of plants at that particular stage of development.

The cold temperatures of early April delayed the growing season by about a week as compared with the previous two years. McWilliams and Ludwig (1972) noted the later flowering of plants in the Matthaei Botanical Gardens, Ann Arbor, in 1971 as compared with the previous two years and attributed much of this to below average precipitation. The warm, moist conditions of April 11 and 12 initiated the growing season. Growth occurred most rapidly after warm, moist weather throughout the growing season. The frosts of October 7 through 11 ended the 1971 growing season.

Woody plant bud break began in April; however, *Vitis riparia, Rhus typhina, Tilia americana,* and *Morus alba* delayed bud break until May. Although flower initiation occurred before leaf expansion in *Acer rubrum, Lindera benzoin,* and *Salix discolor,* the remaining woody species investigated flowered during or after leaf expansion. Full canopy closure occurred in mid-June.

The spring ephemerals were the first herbs to flower, and most completed their above ground life cycles before full canopy closure. Since many of these plants flowered before full vegetative growth was completed, growth continued during fruit development. *Isopyrum biternatum* resumed vegetative growth in the late summer after dying back completely at the time of canopy closure. Photosynthates produced by the vegetative portions of these spring ephemerals that are not used in fruit development are transported to specialized food storage organs such as bulbs, corms, or rhizomes (and less commonly in nodule-like structures located on the roots as in *Isopyrum*

TABLE 1. Phenograms of 45 herbaceous plant species of Sandhill Woodlot.



(Table 1 continued on page 16)

Table 1 continued

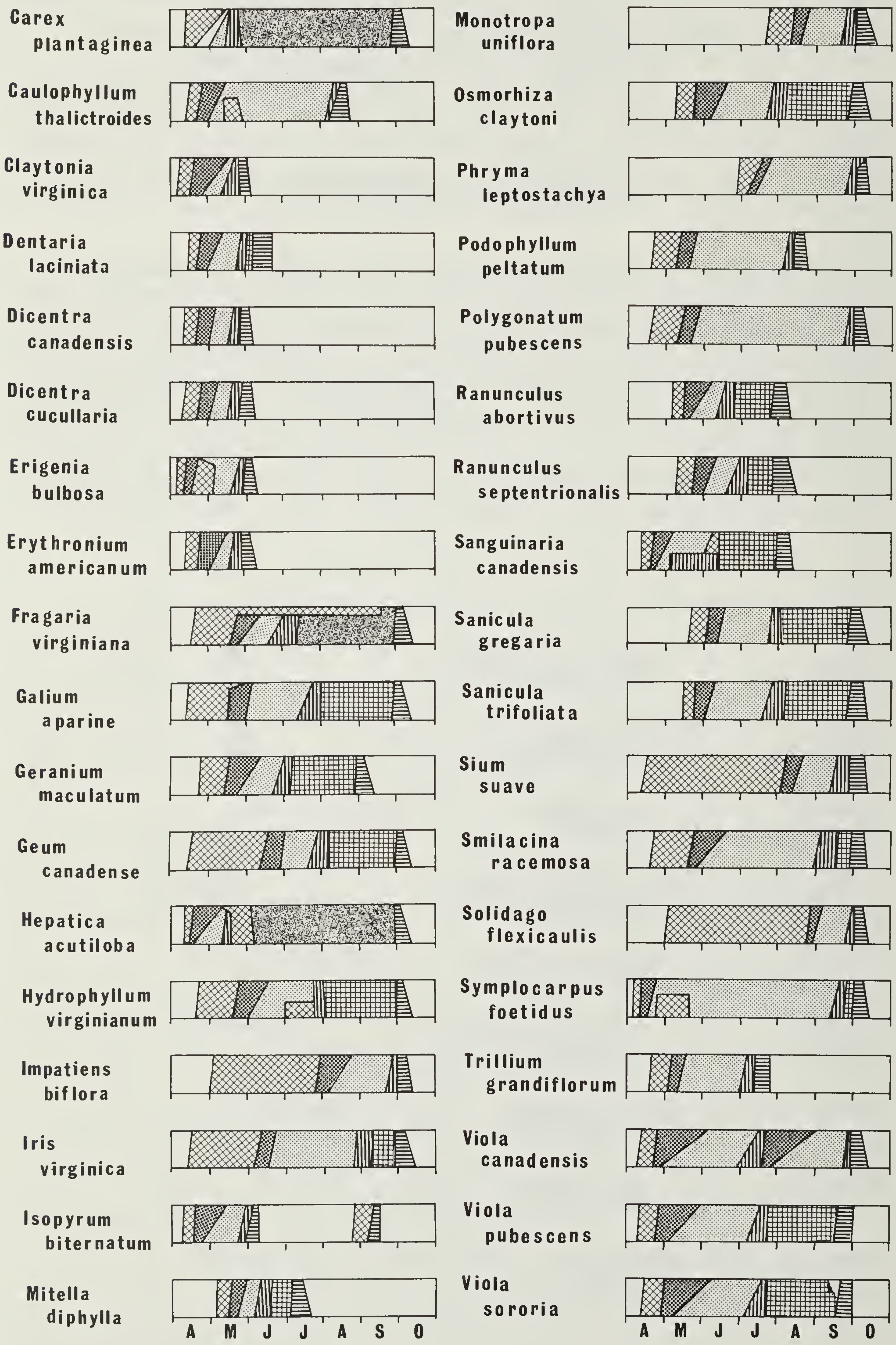
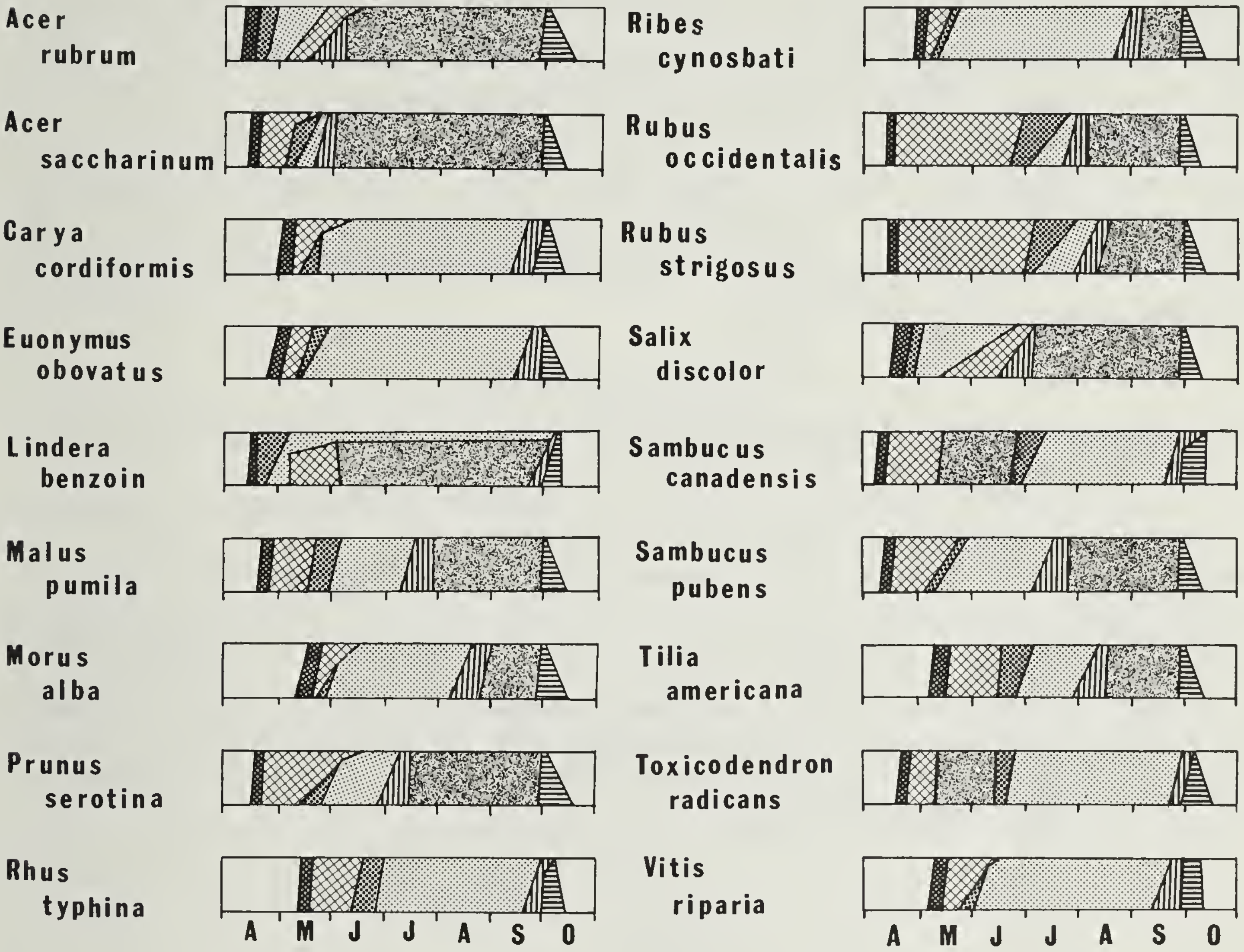


TABLE 2. Phenograms of 18 woody plant species of Sandhill Woodlot.



biternatum). These reserves are utilized in bud formation in the fall and in the rapid bud and shoot expansion the following spring. Some species, such as *Erythronium americanum,* must develop a bulb of sufficient size before the plant will flower.

Allium triccocum displayed a total separation of the vegetative phase from the reproductive phase of its life cycle. Vegetatively, it acted as a spring ephemeral and died back when the forest canopy closed. Solitary umbellate inflorescences appeared in July apparently using photosynthates stored in the bulbs during the vegetative phase of its life cycle.

The majority of the herbs studied were not active the entire growing season. Late summer and fall flowering species grew vegetatively for most of the season while spring flowering species usually persisted in a partially senescent state until seed dispersal. Those senescent aerial portions remaining after seed dispersal and the active fall flowering species were killed by the heavy frosts of October 7 through 9, about the time of peak deciduous tree coloration.

Occasionally the phenology of two or more species of a single genus was investigated. It was observed that the species of such genera usually peaked flowering at different times. Even the two spring ephemeral *Dicentra* species, whose entire life cycles are completed within the same two months, overlapped flowering times by only a week of their individual three week flowering periods. *Cardamine bulbosa* initiated growth three weeks after *C. douglassii*, and *Acer saccharum* bud break occurred one week after that of *A. rubrum*. This delay of growth initiation prevented concurrent flowering in these species. Although *Sambucus canadensis* and *S. pubens* were active during the same period, their flowering periods were separated by a month. The *Viola* species were an exception since all three species studied flowered at the same time. However, unlike the other two species, *Viola canadensis* initiated a second flowering period in late July. By flowering at different times, these sympatric, intrageneric species can minimize unsuccessful cross pollination and possible interspecific hybridization.

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Review

NOVA SCOTIAN BOLETES. By D. W. Grund and K. A. Harrison. J. Cramer, Vaduz. 1976. 283 pp. DM 60 (ca. US$24.00).

Grund and Harrison present descriptions of 80 bolete taxa which occur in Nova Scotia or are likely to occur there. Line drawings of important microscopic characters and data on edibility, when available, accompany each description. Sixty-eight excellent plates of black and white photographs highlight the work and illustrate most taxa including two species, *Boletus pseudopeckii* and *B. miniato-pallescens* described from Michigan and not previously illustrated. Three new varieties are described and two new combinations are made. A synoptic key to species as well as dichotomous keys are given. Unfortunately, no guidance is given on the use of the synoptic keys aside from citing two references which are not likely to be available to non-professional mycologists. The book is an example of an admirable effort to lower publication costs by having camera-ready copy prepared by the authors and reproduced as submitted. The initials of the junior author are reversed on the cover and a few cases where a publication is cited under one year in the text and a different year in the Literature Cited were noted, but in general the book is well done and will be a valuable reference for Nova Scotia and eastern Canada generally, as well as New England. Scientifically it will be of great value in comparing bolete floras of different regions.

–Nancy Weber

VEGETATION AND FLORISTICS OF A SAND SPOIL DEPOSIT–BARKER'S ISLAND IN SUPERIOR HARBOR, DOUGLAS COUNTY, WISCONSIN[1]

Simon Dabydeen
School of Life Sciences
University of Nebraska, Lincoln, Nebraska 16850

Rudy G. Koch
Department of Biology
University of Wisconsin–Superior, Wisconsin 54880

Two natural sand bars, Minnesota and Wisconsin Points, nearly 10 miles long, separate Lake Superior from Superior Bay. This natural bay, at the westernmost tip of Lake Superior, connects with the St. Louis and the Nemadji Rivers, which exit between the two points and through a manmade opening in Minnesota Point. The Duluth–Superior harbors are located inside the bay. Early records indicate that the bay was generally five to ten feet deep, with mats of floating vegetation (Mengel, 1971). As commercial navigation increased with greater utilization of the region's natural resources, it became necessary to deepen the navigation channels. The dredged spoils were variously deposited on land, in selected spots in the bay, thus "making land," or dumped into Lake Superior. This report concerns the vegetation of one of these deposits, Barker's Island, in Superior Harbor at Superior, Douglas County, Wisconsin.

Barker's Island is approximately 600 feet wide by 5,500 feet long. It is connected to the mainland by a causeway (figure 1). The major part of the island (which is composed entirely of dredged spoil deposits totaling some 1.5 million cubic yards) was formed from 1897 to 1902, though smaller deposits were made as recently as 1964. It varies in elevation from near lake level at the north end to as much as 12 feet above the lake toward the south end. The sandy fill material and the underlying sands of the bay's bottom extend approximately 25 feet beneath the water surface where they rest on the red clays typical of the western tip of Lake Superior.

Work relating to revegetation of dredged spoils is not extensive. McVaugh (1947, 1957) reported on vegetation of dredged areas in New York. The Corps of Engineers has generated a number of studies relating to the disposal of spoils, and technical reports are available through their offices. Lakela (1939) described early vegetation on a fill site the Oatka Beach Addition, along Minnesota Point in the Duluth–Superior area. Bernard and Davidson (1969) studied the same area in 1967 and described the changing vegetation. Recent interest in the polluted nature of many dredged materials has increased the need for understanding the role of vegetation in protecting and stabilizing on-land spoil deposits. Our analysis of vegetation on Barker's Island should aid in understanding the development of vegetation on other spoil deposits, particularly in western Lake Superior.

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[1] Center for Lake Superior Environmental Studies Publication No. 17.

On the basis of aerial photographs and ground reconnaisance, major vegetational stands (figure 1) were determined. The delimitation of these stands (referred to as sites in the following discussion) defines the major deposition sites during the history of the island. (Some areas were devoid of vegetation. These include parking lots, recent or active borrow pits, roads, and new construction for berthing the *Meteor,* one of the whalebacks originally built in Superior and now forming the nucleus of a developing tourist trade. These areas are not considered further.)

SITE I (Wet Flats). This is a low area in the northeastern portion of the island. Several shallow pools containing a number of submerged and floating aquatics are surrounded by dense stands of false loosestrife *(Lythrum salicaria).* Cat-tails *(Typha latifolia)* and bulrushes (*Scirpus* sp.) are abundant. During times of higher lake levels, some portions of the site are flooded, resulting in dense growths of the moss, *Leptodictyum riparium,* among emergent stems. The substrate is sand with sparse amounts of finer clay. In some parts of the area a thin layer of organic material may be found on the soil surface. The watertable is at the surface. This site, as well as sites II and

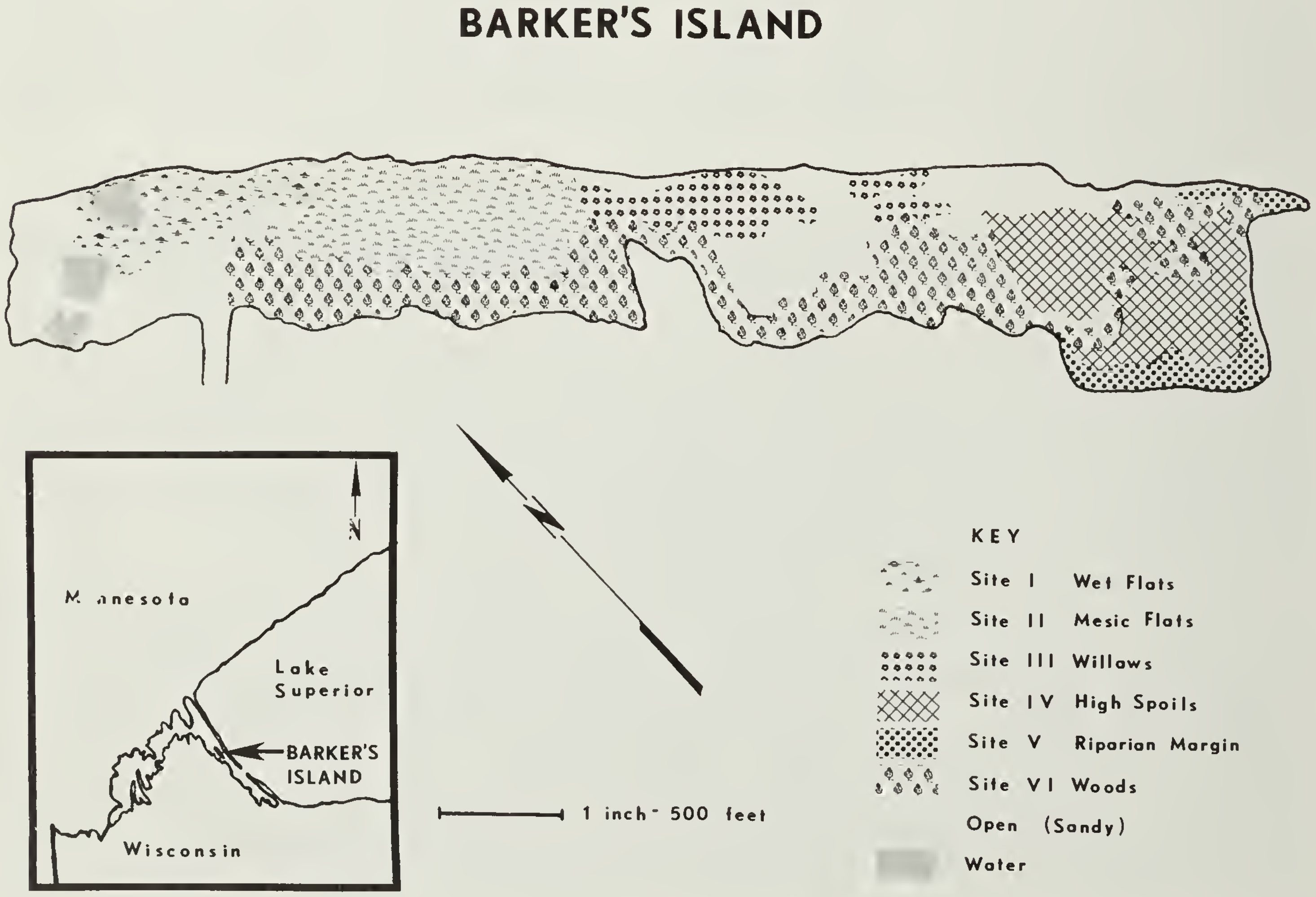
BARKER'S ISLAND
N
Minnesota
Lake Superior
BARKER'S ISLAND
Wisconsin
1 inch - 500 feet
KEY
Site I Wet Flats
Site II Mesic Flats
Site III Willows
Site IV High Spoils
Site V Riparian Margin
Site VI Woods
Open (Sandy)
Water

Fig. 1. Map of Barker's Island, Superior Harbor (Douglas County, Wisconsin), showing the location of the island (insert) and the vegetation stands (sites) on the island.

III, last received deposits in 1954, though moderate borrowing activity persisted until 1972.

SITE II (Mesic Flats). Just south of the above site is a relatively flat area which is some six to twelve inches higher. Although the harbor is well protected, limited wave action does occur, and this part of the island seems to be most exposed to waves. During heavy seas waves break onto the site, but there is only limited wave erosion. The site receives some disturbance by man, chiefly in the form of bicycle and motorbike activity. Vegetation appears to be most affected by changes in lake level. Because of higher levels in 1974 and 1975, the species composition has become more hydric. For instance, false loosestrife was uncommon before 1972 but abundant in 1975. The vegetation includes a variety of sedges (*Carex* sp.), grass of Parnassis (*Parnassia palustris*), rushes (*Juncus* sp.), and *Gerardia tenuifolia.* The total biomass is the lowest of all sites except for parts of site IV. Plants are sparsely distributed and short in stature. The substrate is similar to that of site I.

SITE III (Willows). Typically, the elevation here is from four to six feet, and the substrate contains relatively more organic material and fine clay than in the other deposits. The vegetation is denser, and the total biomass is the highest of all the sites. The principal species is willow (*Salix interior*), which contributes over 50% of the biomass in the study plots.

SITE IV (High Spoils). This site, comprising much of the southern end of the island, is the most diversified in cover. The most recent deposit (1964), it is also the highest, gradually sloping from 12 feet on the bay side to one foot or less on the land side. In some regions vegetational cover—chiefly beach pea *(Lathyrus maritimus)* and false heather *(Hudsonia tomentosa)*—is quite dense. In other areas cover consists of scattered individuals of galingale *(Cyperus schweinitzii),* jointweed *(Polygonella articulata),* and wormwood *(Artemesia biennis).* Organic material in the substrate is low in vegetated areas and nearly absent in more exposed regions.

The reason for poor revegetation in the central part of site IV is not clear, though there are obvious signs of vegetational damage from vehicular traffic. Since the area is higher, it is exposed to greater wind velocities than other sites, but the highest areas of this site frequently are the places of denser cover. Initially it was thought that spoils in this area might contain a substance toxic to plant growth, but greenhouse tests comparing growth on various sand substrates with samples from the area, showed no significant differences. Since soil moisture is available within two to six inches of the surface, it would appear that a major retarding factor is disturbance.

SITE V (Riparian Margins). Contrasting sharply with the sparse vegetation of site IV, the lower and wetter west and south edges of the island around site IV support vegetational cover typical of more hydric conditions. This narrow band of vegetation is dominated by bulrushes, willow, and false loosestrife. The age of this deposit is the same as for site IV (1964). A thin layer of organic material lies at the surface of the substrate.

SITE VI (Wooded). The first deposit (and the origin of the island) was made at the beginning of the century. Today this section supports a youthful forest comprised chiefly of white birch and alder (table 3). Ground vegetation is diverse and includes poison ivy *(Rhus radicans).* The ground level varies in elevation from low wet depressions near the lake level to ridges nearly six feet higher. There is a shallow (1-2 inch) layer of organic material on the soil.

Collections were made during visits to the island from 1969 to 1975, spaced to allow sampling of spring, summer and fall floras. A complete list of species and the sites from which collections were made is presented in table 1. Voucher specimens are deposited in the herbarium of the University of Wisconsin–Superior (SUWS). One hundred and ninety three taxa representing 53 families were found, the largest families being the Compositae and the Cyperaceae.

In order to compare vegetation of different areas of the island and to obtain quantitative estimates of the principal species, biomass determinations were made late in the growing season of 1973. Six one-meter square plots were randomly selected within each vegetation site and all plants clipped at ground level. They were then sorted by species, oven-dried, and weighed. Additionally, four ten-meter square plots were selected in the forested area and the basal areas of trees and shrubs were determined.

Biomass determinations for each site are reported in table 2. Lowest biomass is reported from site II, though parts of site IV were lower (see discussion above). The wetter aspect of site I probably reduces the amount of human disturbance as composed with that in site II, and this, with more hydric conditions, is apparently a factor in the increased production of site I over site II. Site III has the highest biomass of all sites, although the values for site VI would be higher if trees had been included in the total. The nature of the substrate of site III probably has a major influence on productivity.

The wooded site (VI) represents the oldest community on the island, but the forest is not well developed. The trees are all quite small, averaging less than seven inches in diameter. Paper birch and alder are the dominant species (table 3). A few pines found at the margin of the forest appear to have been planted.

A comparison of the species from the Oatka Beach Addition reported by Bernard and Davidson (1969) was made by using the Index of Similarity (200 c/a+b) where c is the number of species common to the two sets of data and a and b are the number of species in each set. This index (a percentage value) was used by Curtiss (1959) to compare plant communities in Wisconsin. In his work the index varied from 78.9% between the most similar communities (dry prairie and dry-mesic prairie) to 0.4% between least similar communities (open bog and dry prairie). The Barker's Island and Oatka Beach floras have an index of 42.2%, somewhat lower than expected since the areas are geographically close and have a similar substrate. However, the older, forested region on Barker's Island is not represented on Oatka Beach, and disturbance, especially borrow activities, has been greater on Barker's Island.

The relative paucity of woody species (10.4% in our list) characterizes the vegetation of Barker's Island and is consistent with the low figures reported by Lakela (6.9%) and Bernard and Davidson (17.3%). The slow development of forest canopy is also consistent with other studies in the area. The Oatka Beach flora lacked continuous canopy cover 32 years after deposition (Bernard & Davidson, 1969). Willow thickets in both Oatka Beach Addition and Barker's Island, though relatively dense, allow ample light to pass through the canopy to support numerous herbaceous species.

Questions of succession on fill areas are difficult to answer. Lakela (1939) indicated that floristic diversity was simplified by competition, yet this study and that of Bernard and Davidson found the number of species increasing with time, an observation supported by McVaugh (1957). Lakela further suggested that *Acer rubrum* and *Populus deltoides* would become important tree species in the forest. Neither species was found on Barker's Island. McVaugh (1957) noted that succession on the dredged sands was greatly retarded, an observation which agrees with ours. Because of borrow activities as well as topographic and substrate differences between sites, it is not possible to compare vegetation on the different sites as representative of successional stages. Yet it is apparent that major floristic differences exist between early and later deposits.

TABLE 1. List of taxa found on Barker's Island. Roman numerals following the names refer to the site from which the plants were collected, as described in the text. "W" indicates plants collected in waste places. Nomenclature, in most instances, follows Gleason & Cronquist (1963).

Alismataceae
Alisma subcordatum I
Sagittaria latifolia I
Anacardiaceae
Rhus radicans VI
Araceae
Calla palustris I
Asclepiadaceae
Asclepias syriaca II
Balsaminaceae
Impatiens biflora VI
Betulaceae
Alnus rugosa VI
Betula papyrifera VI
Boraginaceae
Lappula echinata W
Myosotis arvensis W
Campanulaceae
Campanula rapunculoides VI
Caprifoliaceae
Sambucus pubens VI
Caryophyllaceae
Cerastium viscosum II, VI
Silene cucubalus II
Stellaria longifolia I
Chenopodiaceae
Chenopodium album II, III
Corispermum hyssopifolium II
Cycloloma atriplicifolium II
Ceratophyllaceae
Ceratophyllum demersum I

Cistaceae
Hudsonia tomentosa IV
Compositae
Achillea millefolium III
Ambrosia artemisiifolia II, IV
Anaphalis margaritacea VI
Antennaria neglecta III
Arctium lappa II
Artemesia biennis II, III, IV
Aster brachyactis II
A. ciliolatus III
A. junciformis III
A. macrphyllus VI
A. sagittifolius VI
A. simplex III
Bidens cernua I, II
B. frondosa I, II
B. tripartita I, II
B. vulgata II
Chrysanthemum leucanthemum III
Cirsium arvense II, III
C. vulgare III
Crepis tectorum II
Conyza canadensis II
Erigeron philadelphicus III
E. strigosus II, III
Eupatorium maculatum III, VI
Grindelia squarrosa II
Helianthus giganteus III
Hieracium aurantiacum II, III
H. canadense II

Compositae (Cont'd.)

Lactuca biennis W
Matricaria maritima II
M. matricaroides II
Rudbeckia hirta III
Senecio pauperculus V
S. vulgaris II
Solidago gigantea var. serotina III
S. juncea III
Sonchus arvensis III
S. oleraceus III
Tanacetum vulgare II, III, VI
Taraxacum officinale III, VI
Xanthium strumarium III

Cornaceae

Cornus stolonifera VI

Cruciferae

Barbarea vulgaris III
Berteroa incana III
Brassica kaber III
Camelina microcarpa W
Lepidium densiflorum II
Rorippa islandica var. fernaldiana I, V, VI
Thlaspi arvense W

Cyperaceae

Carex crawfordii I, V
C. hystricina I, V
C. projecta I, V
C. retrorsa I, II, V
C. vulpinoidea I, II
C. viridula V
Cyperus schweinitzii IV
Eleocharis acicularis I
E. intermedia I
Scirpus americanus I, V
S. cyperinus I, V
S. rubrotinctus V
S. torreyi I
S. validus var. creber I, V

Cucurbitaceae

Echinocystis lobata VI

Equisetaceae

Equisetum hyemale I, II, III, V
E. laevigatum V

Ericaceae

Pyrola elliptica VI
P. rotundifolia VI

Gentianaceae

Gentiana andrewsii I

Gramineae

Agrostis scabra II
Beckmannia syzigachne V
Echinochloa pungens II
Elymus canadensis IV, V
Hordeum jubatum W, II, III
Phleum pratense III
Setaria glauca III

Gramineae (Cont'd.)

Sphenopholis obtusata II
Sporobolus cryptandrus II
Poa compressa III

Guttiferae

Hypericum majus V

Hydrocharitaceae

Anacharis canadensis I

Iridaceae

Iris versicolor I

Juncaceae

Juncus bufonius I, V
J. effusus var. solutus I, V
J. nodosus I
J. torreyi I

Labiatae

Dracocephalum formosius I
Galeopsis tetrahit II
Lycopus asper I
L. uniflorus I, V
Mentha arvensis V
Prunella vulgaris V
Scutellaria galericulata V
Stachys palustris I
S. hispida I

Leguminosae

Lathyrus maritimus III, IV
Melilotus alba II
M. officinale II
Trifolium hybridum II
T. pratense II, III
T. procumbens III
T. repens II, III

Lemnaceae

Lemna minor I
L. trisulca I

Lentibulariaceae

Utricularia vulgaris I

Liliaceae

Maianthemum canadense VI
Polygonatum pubescens VI
Smilacina stellata VI

Lythraceae

Lythrum salicaria I, V

Myricaceae

Myrica gale I, V

Najadaceae

Potamageton foliosus I
P. pusillus I
P. zosteriformis I

Onagraceae

Oenothera parviflora III, IV
Epilobium angustifolium III
E. palustre III

Orchidaceae

Corallorhiza trifida VI
Habenaria hyberborea V
Liparis loeselii V
Spiranthes cernua II, V

Plantaginaceae
Plantago major II
Pinaceae
Juniperus communis var. depressa III
Picea glauca VI
Pinus banksiana VI
P. strobus VI
Polygonaceae
Polygonella articulata IV
Polygonum aviculare W, II
P. lapathifolium I
P. punctatum V
Rumex acetosella II
R. altissimus III
R. maritimus II
R. mexicanus II, III
Polypodiaceae
Athyrium filix-femina VI
Primulaceae
Lysimachia ciliata V, VI
L. quadrifolia V
Ranunculaceae
Caltha palustris I, V
Clematis virginiana W
Ranunculus acris II, III
R. septentrionalis V
Thalictrum dioicum VI
Rosaceae
Agrimonia striata III
Fragaria virginiana III
Geum macrophyllum III
Potentilla norvegica II
Rosa blanda III
R. rugosa VI
Rubus setosus III
R. strigosus III, VI
Salicaceae
Populus balsamifera VI
P. deltoides VI
P. tremuloides V, VI
Salix interior I, II, V, VI
S. rigida V, VI
Saxifragaceae
Parnassia palustris II
Ribes americana VI
Scrophulariaceae
Gerardia tenuifolia II, VI
Linaria vulgaris W, II, III
Mimulus ringens I, V
Solanaceae
Solanum dulcamara VI
Sparganiaceae
Sparganium eurycarpum IV
Typhaceae
Typha angustifolia I
T. latifolia I, V
Umbelliferae
Carum carvi W
Cicuta bulbifera I
C. maculata I, V
Heracleum lanatum VI
Osmorhiza longistylis VI
Sanicula marilandica VI
Urticaceae
Laportea canadensis VI
Urtica dioica VI
Violaceae
Viola conspersa VI
Vitaceae
Parthenocissus inserta VI

TABLE 2. Vegetation composition by site determined on the basis of the five dominant species present. (mean number/mean weight in grams per m²)

Site	I	II	III	IV	V	VI
Artemisia biennis				10.8/50.9		
Aster spp.		14.5/20.4	4.3/22.3			
Cornus stolonifera					0.3/24.9	1/17.8
Elymus canadensis			11.5/28.6			
Equisetum hyemale			14/14.9		6.8/12.9	
Gerardia tenuifolia		22.5/8.8				
Hieracium aurantiacum				1.8/7.7		
Hudsonia tomentosa				6.3/13.6		
Juncus effusus		31.8/8.1				
Lathyrus japonicus		2.5/16.4				
Linaria vulgaris				24/24.7		
Lythrum salicaria	9.5/115.5				12.5/74.5	
Myrica gale	0.5/23.8					
Polygonum lapathifolium	3/42.8					
Rubus strigosus						5.5/16.2

TABLE 2. (Continued)

Site	I	II	III	IV	V	VI
Sambucus pubens						0.3/8.1
Salix interior		2.8/8.5	9/313.6		4.5/80.5	
Scirpus spp.	14/21.0				14.5/17.9	
Solidago spp.				3.5/16.1		18/80.3
Sonchus arvensis			6.5/17.9			
Tanacetum vulgare						1.8/18.9
Typha latifolia	2.3/33.9					
Mean Total Biomass (g/m^2)	295.6	78.8	546.7	137.6	236.6	187.2

TABLE 3. Woody Species Composition of Site VI. (Average of Four Plots)

Species	Individual Stems/10m^2	Basal Area in Square Inches/10m^2
Trees:		
Betula papyrifera	6	196.5
Populus balsamifera	2	81.8
Populus tremuloides	0.5	1.7
Shrub:		
Alnus rugosa	23	166.7

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CONTENTS

Natural Dyeing with Plants in Michigan
Jane I. LaRue 3

The Chemical Inhibition of Competitors by Smooth Sumac (*Rhus glabra*)
Andrew G. Stephenson 15

The Impact of Snowmobiling on Ground Layer Vegetation near Sage Lake, Ogemaw County, Michigan
Richard H. Baetsen 19

Additions to the Flora of Allegan County
Steven G. Bruggers and Paul Van Faasen 26

Life-forms in the Michigan Flora
John W. Thieret 27

A Botanical Inventory of Sandhill Woodlot, Ingham County
III. Phenology Study
Darlene M. Frye . . . .

Review 38

Vegetation and Floristics of a Sand Spoil Deposit—Barker's Island in Superior Harbor, Douglas County, Wisconsin
Simon Dabydeen and Rudy G. Koch 39

On the cover: Paper birch
North of Cross Village, Emmet County
(T. Lawrence Mellichamp, March 7, 1973)

33
.16
.2

Vol. 16, No. 2

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CHROMOSOME STUDIES OF SOME MOSSES OF THE DOUGLAS LAKE REGION. IV

Jerry A. Snider

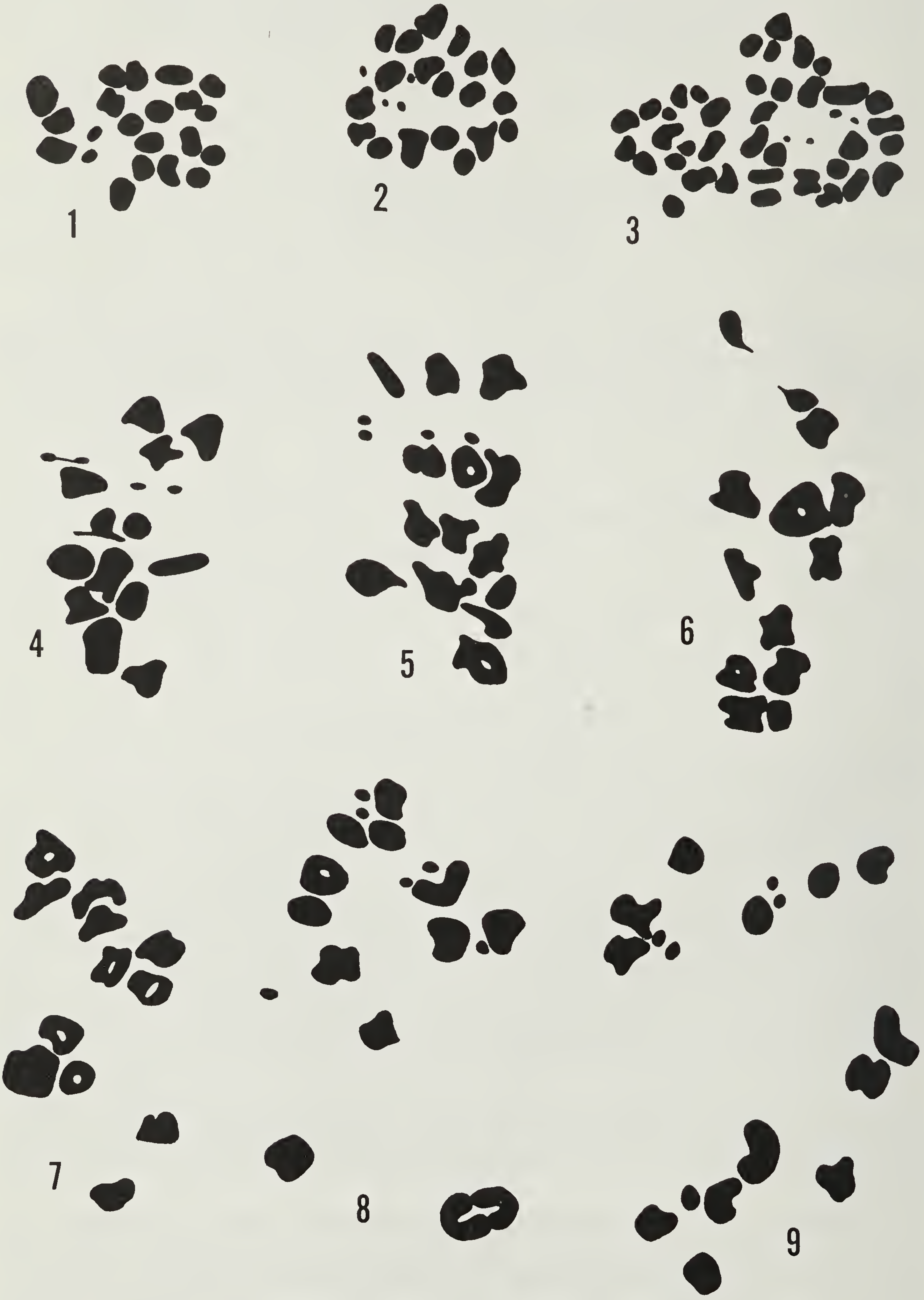
Department of Biological Sciences
University of Cincinnati
Cincinnati, Ohio, 45221

Meiotic chromosome counts of 22 species of mosses from the Douglas Lake region of northern Michigan have been published to date (Snider, 1970, 1972, 1973). Observations on the chromosome number and meiotic behavior of the following eight species are a continuation of that study. Methods and techniques utilized are those of Snider (1970). Voucher specimens are deposited in the herbarium of the University of Cincinnati.

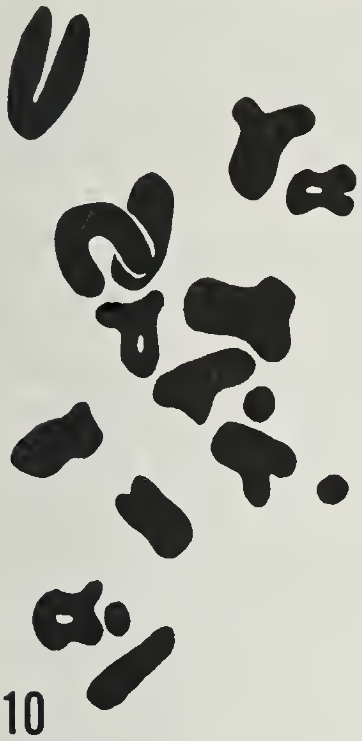
Sphagnum recurvum P. Beauv–n = 19 + 2 (figs. 1,2). Emmet Co., *Snider 1873.* Bryan (1955) estimated 17 to 19 chromosomes from observations of somatic tissue in plants from Washtenaw Co., Michigan. Counts from the Emmet Co. population agree with those made by Smith & Newton (1968) on material from Great Britain–n = 19 + 2. From several counts taken, two bivalents appeared to be somewhat larger, and the others were rather uniform in size. The m-bivalents were typically much smaller and stained faintly; each underwent precocious disjunction, occasionally to the point of separating into their respective sister chromatids (fig. 2).

Sphagnum warnstorfii Russ.–n = 38 + 2(?) (fig. 3). Cheboygan Co., *Snider 1875.* Holmen (1955) reported the number n = 19 + 4 on material from Denmark and Sweden. The Cheboygan Co. population is apparently a polyploid race. The 38 bivalents were rather uniform in size and behaved normally during meiosis. The two small, faintly stained m-bivalents exhibited early disjunction during metaphase. All previous reports of polyploid species of *Sphagnum* describe four m-bivalents as typically occurring in the complement. Although the chromosomes in the Michigan plants did tend to resist uniform spreading and could possibly obscure the smaller, faintly stained m's, in the several preparations studied only two pairs of m-bivalents could be discerned. This is the first reported count on this species in North America, and the occurrence of the diploid race in North America must await verification.

Dicranum bonjeanii DeNot. *ex* Lisa–n = 13 + 1 (figs. 4,5). Presque Isle Co., *Snider 1880.* This makes the third reported count for this species and the first count for North American material. Briggs (1964) published the number n = 11 from populations in Great Britain in which she observed a large, heteromorphic bivalent disjoining early. Ramsay (1968), also working on a population from the British Isles, reported the number n = 12 from mitotic preparations on gametophytic tissue. She recognized three large, six medium,



Figs. 1-2. *Sphagnum recurvum,* n = 19 + 2. 3. *Sphagnum warnstorfii,* n = 38 + 2. 4-5. *Dicranum bonjeanii,* n = 13 + 1. 6-7. *Dicranum polysetum,* n = 12. 8-9. *Dicranum polysetum.* n = 12 + 3. (All drawings ca. × 3500, made from photographic negatives.)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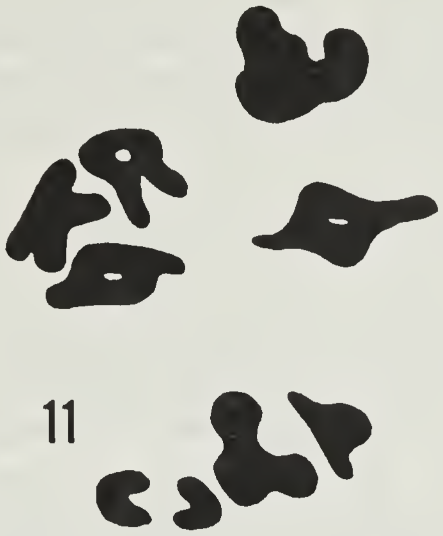
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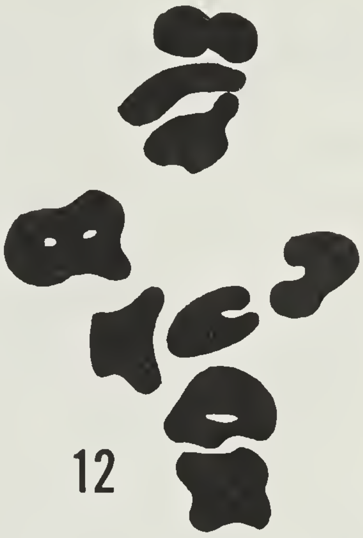
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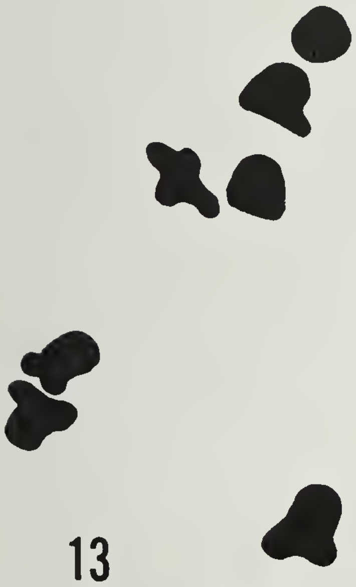
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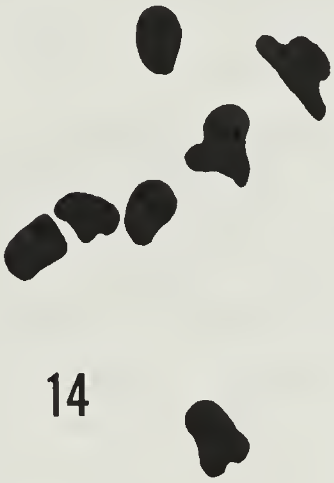
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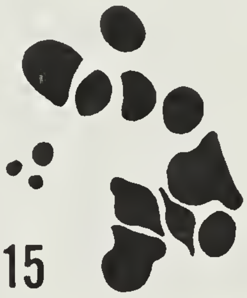
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Fig. 10. *Dicranum polysetum,* n = 12 + 3. 11-12. *Mnium spinulosum,* n = 8. 13-14. *Orthotrichum speciosum,* n = 7. 15. *Hypnum pallescens,* n = 10 + 1. (All drawings ca. X 3500, made from photographic negatives.)

and three small chromosomes. In Michigan material four size groups were recognized, including the small m-bivalent. Three large bivalents consisting of two with terminal or subterminal kinetochores and one with a median kinetochore were observed, the latter bivalent occasionally undergoing early disjunction (fig. 5). Seven medium-sized bivalents appeared to consist of one with a subterminal kinetochore, four with terminal kinetochores, and two with median kinetochores. Kinetochore location in the next two smaller bivalents could not be determined. The small m-bivalent was faintly stained and disjoined into four chromatids during late metaphase or early anaphase (figs. 4,5). It is no surprise that different chromosome numbers have been reported for this questionable species. Crum (1976) felt that *Dicranum bonjeanii*, at least in North America, may be nothing more than an ecological variant of converging growth forms of *Dicranum scoparium* and *Dicranum polysetum*. From the cytological evidence, *Dicranum bonjeanii* poses an interesting taxonomic problem, and a cytotaxonomic study similar to that done by Lowry (1948) with the genus *Mnium* is strongly desired.

Dicranum polysetum Sw.–n = 12 (figs. 6,7); n = 12 + 3 (figs. 8,9,10). Cheboygan Co., *Snider 1872, 1874.* The number n = 12 has been previously reported from Douglas Lake populations (Snider, 1972). In one of the current populations studied (*Snider 1872*) 12 deeply staining bivalents were also observed, consisting of three large bivalents, one of which occasionally disjoined early, eight medium bivalents, and one small bivalent. The second population (*Snider 1874*) studied had the number n = 12 + 3. The complement in this population was also comprised of three larger bivalents, one of which constantly underwent early disjunction and appeared to be heteromorphic (figs. 8,9,10). The nine remaining bivalents were rather uniform in size, and the three m-bivalents present were small and faintly stained. The m-bivalents were observed in varying stages of division: in the undivided state (fig. 10); as two pairs disjoined into half-bivalents and one bivalent undivided (fig. 9); and as all three pairs disjoined into half-bivalents (fig. 8). Further disjunction of the m's into sister chromatids during first division was also observed in several preparations. Holmen (1958) observed a single m-bivalent in Danish material of this species.

Mnium spinulosum B.S.G.–n = 8 (figs. 11, 12). Presque Isle Co., *Snider 1878.* The number n = 8 has already been reported on North American populations of this species by Lowry (1948), Anderson & Crum (1958), and Ireland (1967). This is the only species of *Mnium* known to have eight chromosomes. In the Presque Isle Co. population one smaller bivalent was observed to disjoin earlier than the others (figs. 11,12), and the largest bivalent was consistently the last of the complement to disjoin during anaphase.

Orthotrichum speciosum Nees *ex* Sturm–n = 7 (figs. 13,14). Mackinac Co., *Snider 1876, 1876a.* Vaarama (1950), Steere (1954), and Anderson & Crum (1958) all reported the number n = 6 for this species. In these reports one larger bivalent was always observed. The present count represents the first report of aneuploidy occurring in the species of *Orthotrichum* having superficial stomates. At least 10 capsules were studied from two collections of this species. One collection was taken from a small boulder and the second from a tree trunk adjacent to the boulder. The material was easy to prepare, and the bivalents stained darkly and spread evenly when squashed. In all preparations seven bivalents were easily visible. One slightly larger bivalent containing two chiasmata was present, and three slightly smaller bivalents with subterminal kinetochores and three bivalents with median kinetochores were also observed.

Hypnum pallescens (Hedw.) P. Beauv.–n = 10 + 1 (fig. 15). Chippewa Co., *Snider 1877*; Presque Isle Co., *Snider 1879.* This is the second report on this species in North America. Snider (1973) reported the number n = 10 + m from populations from the Douglas Lake region. He observed three large bivalents, seven smaller bivalents and a faintly staining m-bivalent making up the complement. The current counts confirm both the number and the size classes reported in earlier counts.

I wish to thank Howard Crum for verification of determinations and the University of Michigan Biological Station for the use of facilities. This research was supported by a grant from the National Science Foundation (GB38809) to Howard Crum and funds provided by the University of Cincinnati Research Council.

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POLLEN ANALYSIS OF PEAT FROM A SINKHOLE IN THE GARDEN PENINSULA, DELTA COUNTY, MICHIGAN

Ronald O. Kapp and Thomas P. Means

Alma College, Alma, Michigan, 48801

The discovery of a peat deposit in a small sinkhole provided an opportunity to extend our understanding of the history of vegetation of Michigan's Garden Peninsula. The peninsula, isolated from the mainland by Big Bay de Noc on the northwest, is at the north end of Lake Michigan (Fig. 1). The lake causes the peninsula to have a more equable climate than the

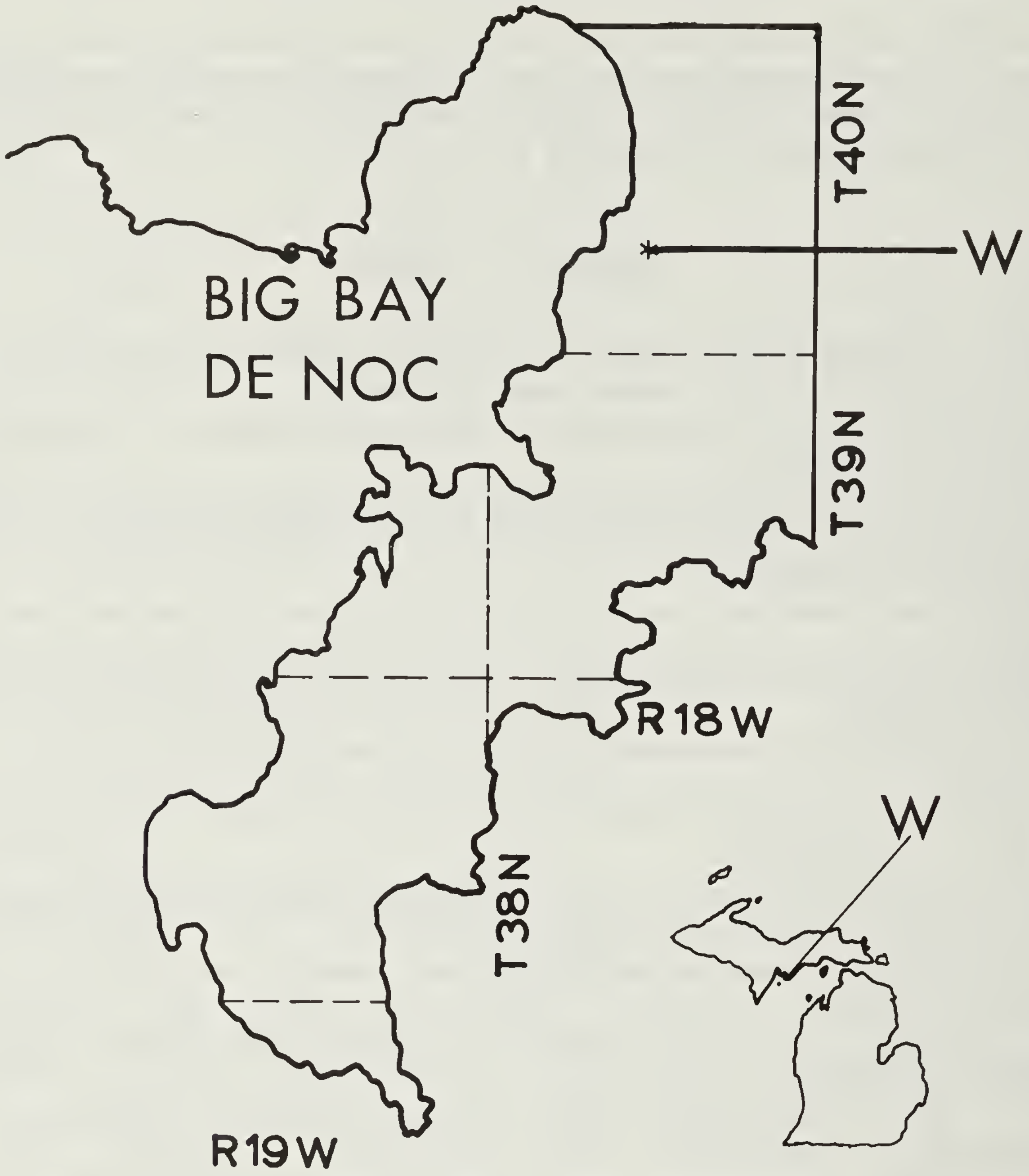

Fig. 1. Location of Winter's Sinkhole (W) one mile east of Big Bay de Noc in Garden Peninsula, Delta County, Michigan.

remainder of Delta County or adjacent areas in the Upper Peninsula of Michigan. Winter average and extreme temperatures of the Garden Peninsula are higher than neighboring mainland areas; climatically the area resembles southern Michigan and southeastern Wisconsin (Visher, 1954). This results in biogeographic affinities with more southerly lake border and eastern deciduous forest communities. The Garden Peninsula, which is at the head of a discontinuous archipelago which extends to Washington Island and the Door Peninsula of Wisconsin, exists primarily because it is underlain by the resistant Niagaran dolomite formation.

The study area, known as Winter's Sinkhole, (NW Cor., Sec. 27, T40N, R18W) is about one mile from Big Bay de Noc and is approximately 80 feet above the level of Lake Michigan (Fig. 1). The sinkhole was formed in Niagaran dolomite, which now outcrops in this area. It was originally a small solution sink about 10 meters in diameter and three meters in depth; the distinctive feature of this site is the existence of *Sphagnum* peat deposits (Fig. 2). It is obvious that this sink held a small peat bog for some time but has been empty long enough that extensive weathering and erosion has left only a remnant of the peat deposits exposed on the northeast side. After holding

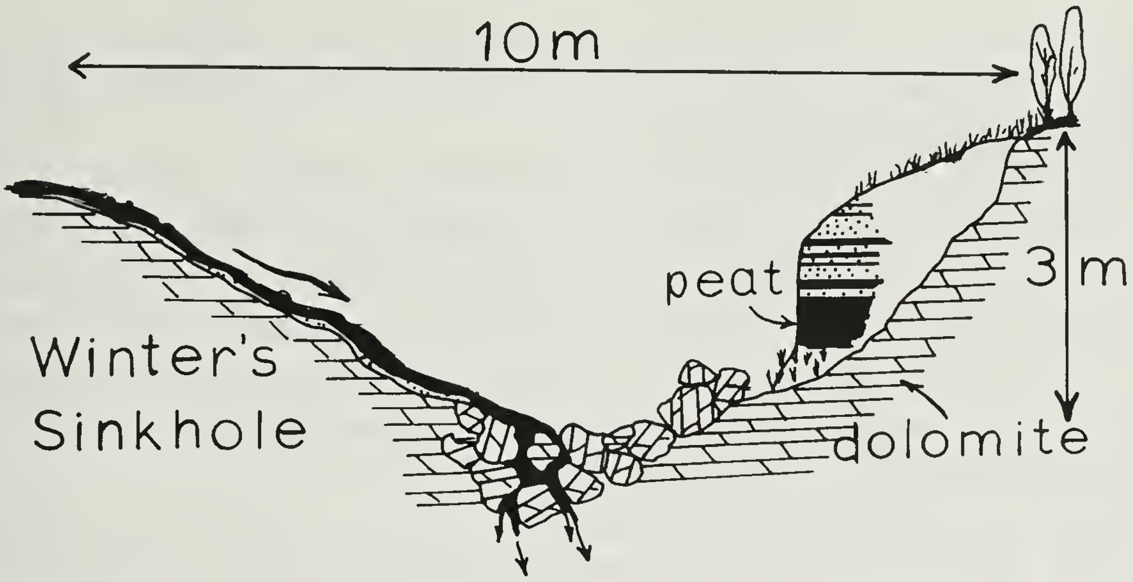

Fig. 2. Diagram of sinkhole exposure in 1975; Maxwell Creek enters from east and disappears in the sink. Top of peat band at asterisk yielded a radiocarbon date of 560 ± 130 B.P. Sediments at the base apparently slumped from the top of the exposure and radiocarbon analysis "strongly suggests that the organic material originated in the post-1950 era" (Sample No. GX-4172 report).

water for some years, the sink collapsed at the deeper level, allowing drainage through rubble at the bottom so that peat deposition was halted; erosion and peat deterioration ensued. A small stream, Maxwell Creek, flows into the sink from the east entering an underground drainage system. The stream may have been recently captured or may have supplied water to the bog from the time of its origin. The drainage may also have shifted away from the sink during certain prehistoric time intervals; this would have interrupted the water supply and temporarily halted the deposition of peaty sediments.

Field sampling was preceded by clearing the vertical face of the peat to a depth of about one meter in order to remove sediments which had been exposed to weathering or which might have been contaminated by modern pollen. The material for analysis was collected by removing at least two cc of sediment at two cm intervals along the vertical exposure; the 39 samples were placed in five gram vials and stored at room temperature.

One cc of sediment was removed from each sample vial for processing. Coarse sand, if present, was removed by differential decanting. The sandy sediments were then treated with hydrofluoric acid to slowly dissolve the siliceous particles. After this process was complete, the samples were further digested by Erdtman's acetolysis procedure (Faegri & Iversen, 1950); at this time, 250 microliters of *Eucalyptus* pollen suspension containing approximately 100,330 grains was added to the sediments so that absolute pollen frequencies could subsequently be calculated. The samples were then suspended in glycerin jelly and slides prepared using 22 X 30 mm cover glasses.

During microscopic examination at 450X, each slide was covered equally by 20-22 transects using a graduated mechanical stage. A complete count, adequate for statistical analysis, required at least 200 grains. Each full count included 200–400 pollen grains of flowering plants and conifers or spores of vascular cryptogams; aquatic pollen types were excluded from the pollen sum. Identification was facilitated by the use of two illustrated keys (Kapp, 1960; McAndrews *et al.*, 1973) and the Alma College reference collection. Grains which were mutilated or degraded too badly to be identified were recorded as unknown; those which were in good condition but could not be identified were recorded as undetermined.

The sedimentary sequence from Winter's Sinkhole (Fig. 3) includes topsoil in the top 10 centimeters; this grades into fine white sand which extends from 10–25 cm. The sand is combined with a minimal amount of *Sphagnum* peat from 25–38 cm and the layer of peat at 38–48 cm is again underlain by a pure sand band for 6 cm. Sand and peat are mixed from 54–72 cm with a pollen-rich peat zone then extending to 85 cm; a block of pure peat was found from 100–150 cm.

Sediments below 1.5 m (beneath the extensive peat block at the base of the sequence shown in Fig. 3) apparently slumped from above even though they were believed to be *in situ* at the time of collection. These alternating sand and peat beds may in fact be the upper deposits in inverted sequence since they are, like the upper sediments, nearly devoid of pollen. A sediment sample from the deepest level (261–263 cm., 103–104 in) upon radiocarbon analysis (GX-4172) "gave 'future' ages on each of the two separate days of counting. This strongly suggests that the organic material originated in the post-1950 era and is thus contaminated with 'bomb C-14' " (quoted from Radiocarbon Determination Report of 28 January 1976 by Krueger Enterprises, Inc., Geochron Laboratories Division).

Sand at all levels was white, very fine grained, well rounded and polished. Some sand may have been blown into the area continuously from the lake shore (only one mile away) or from the dry adjacent uplands. Sand deposition would have been accentuated when the climate was warm and the water levels were lower than normal; West (1961) and Brubaker (1975) found that sand deposition is increased during periods of climatalogical deterioration. At the time of postglacial Lake Nipissing high water, the beach of ancestral Bay de Noc was approximately 0.5 miles from Winter's Sinkhole. Hough (1966) indicates that the Nipissing beach isobases in this area would have been between the present 615 and 625 foot altitudes, representing isostatic rebound of 10-20 feet. The depositional site is now approximately 660 ft. above sea level.

The pollen diagram from sediments of Winter's Sinkhole (Fig. 3) shows the proportion of pollen both on percentage (solid bars) and absolute pollen frequency (line graph) bases. Percentages were calculated using the total pollen sum, exclusive of aquatic pollen types which are presumed to represent local rather than regional paleoecological conditions. The APF scale reflects the number of pollen grains per cc of sediment (scale value ×10,300).

The uppermost sediments were very poor in pollen, possibly due to the porosity of the sandy sediments and thinness of the peaty horizons; percolation of water through the porous sediments causes degradation of pollen. Partial counts were completed in an attempt to determine which species may have been present. The diagram is annotated with symbols denoting species which were only sparsely present (as trace-t) and those which seemed to make up a large percentage of the total (X).

Pollen was well preserved and abundant in the lowermost peaty sediments. For each level in the lower half of the diagram the complete pollen

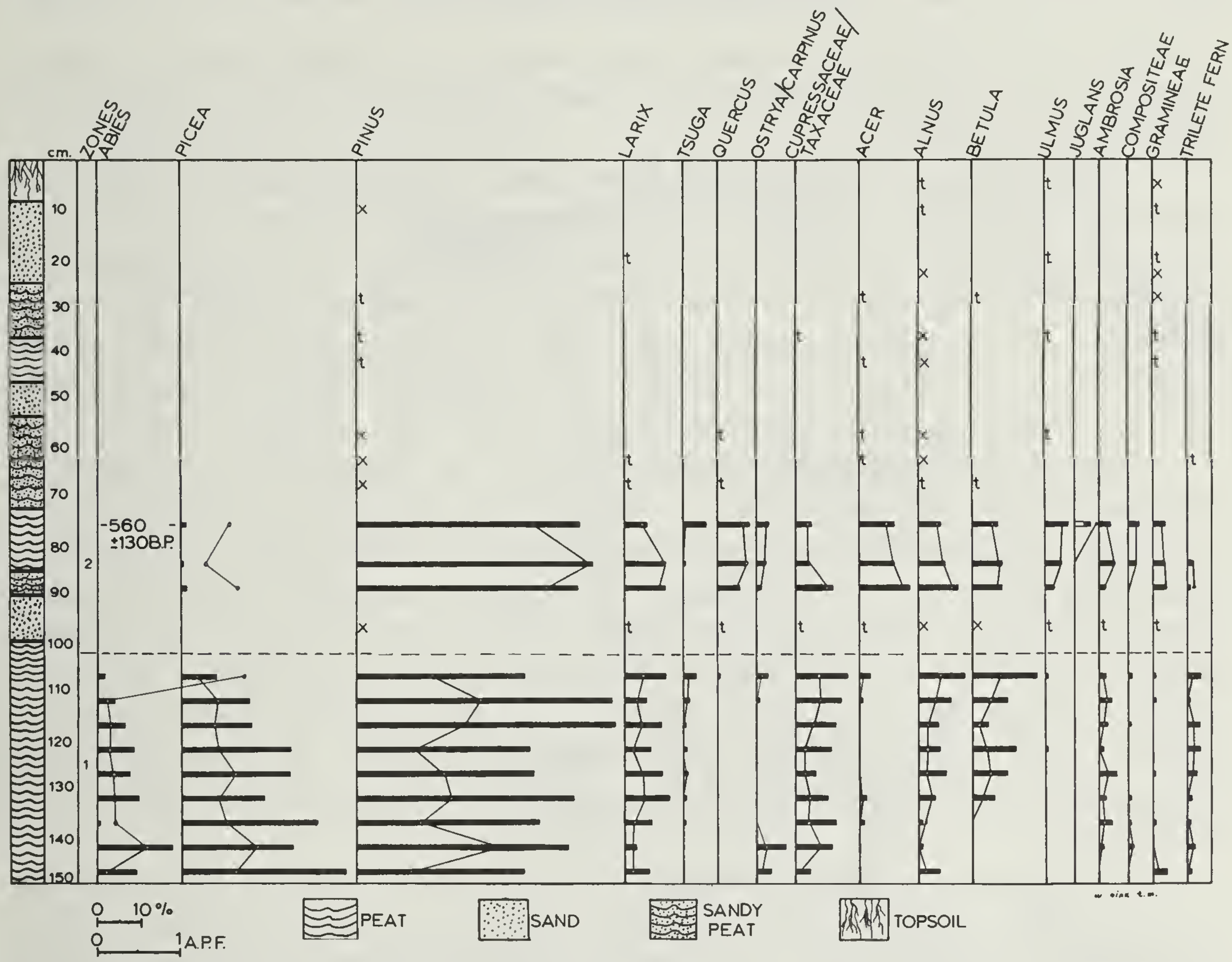

Fig. 3. Pollen diagram from Winter's Sink; solid bars represent percentage pollen frequencies; line graph is absolute pollen frequency (APF). The APF scale multiplied by 100, 300 yields number of pollen grains per cc of sediment.

spectrum has been shown. The diagram has been divided into two pollen zones. Zone 1 (100-150 cm) is dominated by high values of *Abies* (up to 20%), *Picea* (to 45%), and *Pinus* (consistently 40–60%). There are also significant amounts of *Larix* (10–15%), *Alnus*, and *Betula*. This zone also has abundant pollen classified as Cupressaceae/Taxaceae, thought to be either *Juniperus* or *Thuja*, although the two could not be separated from each other or from the genus *Taxus*.

Zone 1 reflects a shift in vegetation from a spruce/fir dominated initial phase to a later stage in which these types diminish while hemlock (*Tsuga*) enters the record and birch (*Betula*) and alder (*Alnus*) increase in abundance.

Pollen Zone 2 is separated from Zone 1 by an indeterminate time span during which peat accumulation was interrupted. Zone 2 is characterized by a total lack of *Abies*, very little *Picea*, and significant amounts of hardwood such as *Quercus, Acer,* and *Ulmus*. An increase in non-arboreal pollen such as *Compositae* and *Ambrosia* occurred. The uppermost sample in this zone yielded unusually high quantities of *Juglans* pollen. The number of pores for 61 *Juglans* pollen grains observed from this level (76 cm) was tallied in an attempt to determine whether both butternut (*J. cinerea*) and black walnut (*J. nigra*) are represented in the pollen record. Sixty of these grains had 7, 8, 9, or 10 pores (n = 11, 28, 16, 5, respectively) and one had 16 pores. On the basis of the report by Whitehead (1963), we conclude that the great majority of these pollen grains (those with fewer pores) are butternut and that black walnut is only sparsely represented, possibly representing long-range drift of pollen from the south.

The uppermost spectrum of Zone 2 has yielded a carbon 14-date of 560 ± 130 years B.P. or 1390 A.D. This provides a minimum date for the arrival of butternut in the Garden Peninsula area; the northermost limit of distribution of that species in Upper Michigan is presently in Delta County. It is possible that butternut extended its range to this region as recently as the eleventh and twelfth centuries A.D., a time known to have been climatically mild in other areas of the northern hemisphere (Bryson & Julian, 1963).

The Winter's Sinkhole pollen diagram is thought to be of early postglacial origin due to the high levels of *Abies, Picea* and minimal amounts of pollen of thermophilous hardwoods during the early parts of the record. Comparing this part of the sequence to standard diagrams from the region (Disterhaft's Farm Bog, Wisconsin, West, 1961; Barney Lake, Beaver Island, Michigan, Kapp *et al.*, 1969; and the Huron Mountains, Michigan, Brubaker, 1975), the high *Abies* and *Picea* levels in the lower parts of Zone 1 seem to represent the early postglacial time. This can be seen by comparing this diagram with the Disterhaft's Farm Bog diagram beginning with Zone 5 to the surface.

An attempt to obtain a radiocarbon date from sediments near the base of the pollen diagram (135–145 cm) proved unsuccessful. These yielded (GX-4456) a "future date" as did the deeper sediments which might have slumped from above. Discussion of this dating anomaly with the director of the dating laboratory (Krueger, personal communication) does not reveal the nature of the problems. Post-1950 origins are virtually impossible and an explanation which depends on weathering or recent carbon-exchange with bomb carbon-enriched atmosphere has little scientific basis. Until an explanation of the anomalous ^{14}C dates can be developed, they must be rejected as inaccurate and excluded from consideration in the interpretations of the pollen diagram.

An approximate date may be postulated on the basis of the first appearance of *Tsuga* in the record. It has been postulated in a recent review (Kapp, 1976) that *Tsuga* entered Michigan along migrational pathways from the east in Ontario (Fig. 4). On the basis of radiocarbon dates from pollen diagrams, *Tsuga* seems to have arrived at Sault Ste. Marie by 6400 B.P., at Beaver Island at 7200 B.P., and in the Huron Mountains at 6000 B.P. The date of arrival of *Tsuga* in the Garden Peninsula area is therefore postulated to be about 7000 to 6000 years before present. We therefore suggest that the oldest sediments from the Winter's Sinkhole pollen diagram, prior to *Tsuga* appearance, exceed 7000 years in age.

The upper portion of pollen Zone 1, from the *Tsuga* appearance to the break at 100 centimeters, probably represents postglacial sediments deposited between 5000 and 7000 years B.P.

The break in peat accumulation may be correlated with the postglacial hypsithermal period. This period was typified by a climate warmer and drier than present, probably with severe fluctuations of Great Lakes water levels

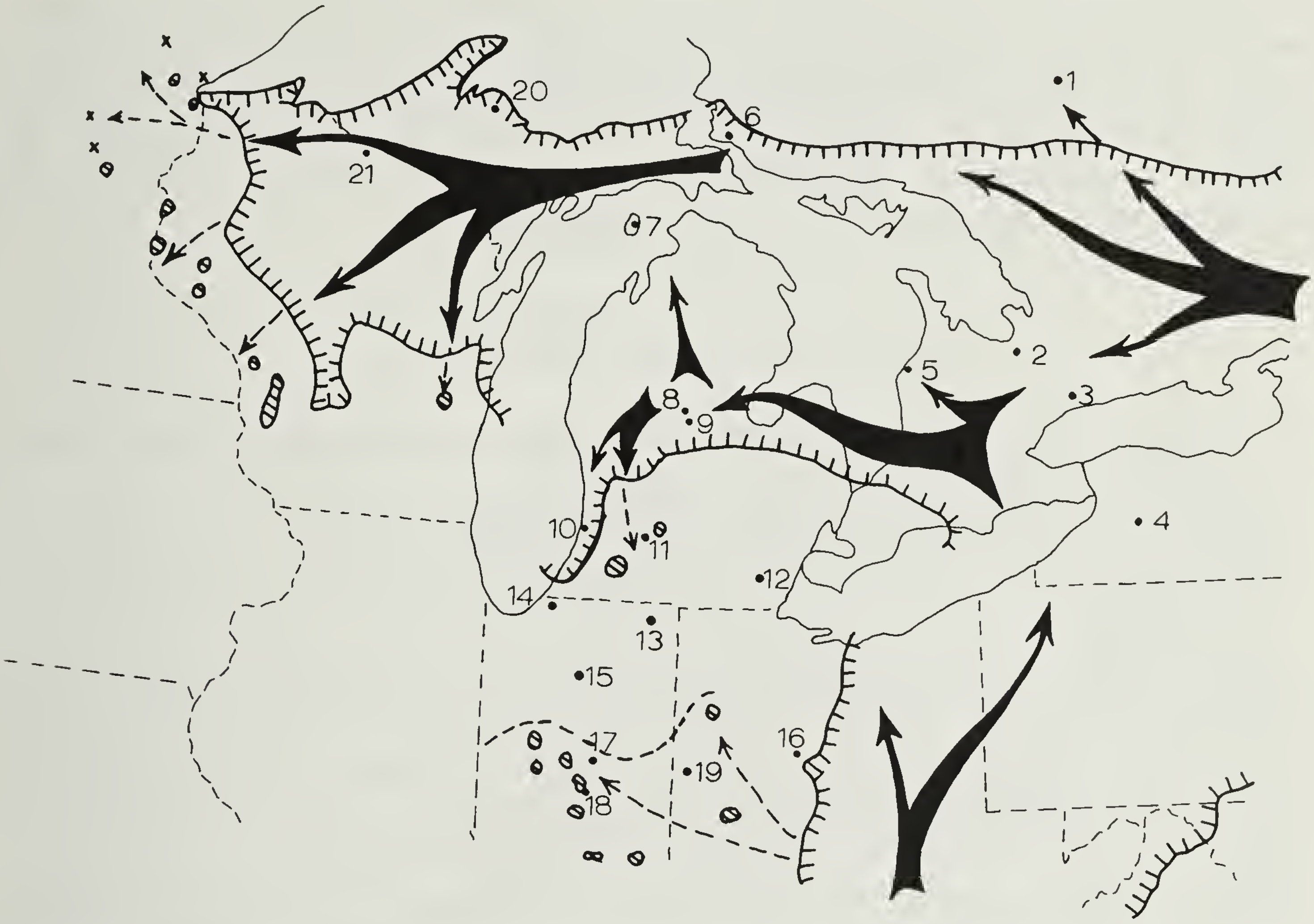

Fig. 4. Postulated migrational pattern of *Tsuga* during the postglacial (from Kapp 1977). Dates of appearance of hemlock pollen in pollen diagrams at sites in the upper Great Lakes region are: (1) 7,300 B.P., (2) 10,200 B.P., (5) 7,600 B.P., (6) 6,400 B.P., (7) 7,200 B.P., (20) 6,000 B.P., (21) 3,650 B.P.

(Bradstreet & Davis, 1975). Such climatic deterioration would have caused the interruption of peat accumulation and allowed the sand layers to form. Bradstreet & Davis concluded that the most frequently cited date of thermal maximum is 5000 years B.P. Postglacial Lake Nipissing is approximately contemporaneous with the hypsithermal interval. This period of high water in the Lake Michigan basin would have brought the active beach to within 800 km of the site; the lake surface would have been about 12 m below the elevation of the sinkhole. Most likely the sandy horizon at 90–100 cm dates from this time.

The peaty sediments at 73–90 cm are thought to have been accumulated between 500 and 2000 years ago; the radiocarbon date of 560 ± 130 B.P. (GX-4171) is from the level of the uppermost pollen spectrum.

The sandy sediments at the top of the sequence, though they have narrow sandy-peat intercalations, are poor in pollen; the trace amounts of pollen present are inadequate for assessing paleoecological changes. These upper sediments apparently date from the past 500 years; the most recent collapse of the sinkhole and erosive destruction of the deposit must have been a very recent phenomenon.

In summary, the pollen diagram from Winter's Sinkhole contains two main pollen zones. The basal zone (estimated to extend from 5000 to greater than 7000 B.P.) is dominated by high levels of *Abies* and *Picea* with small amounts of other arboreal pollen. Zone 2 is characterized by a lack of *Abies*, very little *Picea*, abundant *Pinus*, and significant amounts of other arboreal pollen such as *Larix, Acer, Quercus,* and *Betula.* Unusually high frequencies of *Juglans cinerea* were encountered in a peat horizon radiocarbon dated at 560 ± 130 years B.P.; this provides a minimum date for the migration of butternut to the northern limit of its modern range.

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SCLERIA RETICULARIS NEW TO THE MICHIGAN FLORA

Gary J. Pierce

Department of Biology
Niagara University, New York, 14109

Richard W. Pippen

Department of Biology
Western Michigan University, Kalamazoo, 49008

Scleria reticularis Michx., one of the nut-rushes, is a member of a primarily tropical genus with several representatives reaching into the north temperate zone in eastern North America. Although the plant is an inconspicuous sedge, unimportant from an aesthetic perspective, it is of considerable phytogeographic interest. The distribution of the species (Fig. 1) shows it to be one of the well known "coastal plain disjuncts" (Hanes, 1942; Fernald, 1942; Peattie, 1922).

In the *Michigan Flora* Voss (1972) did not report this species but indicated that its presence in Michigan is to be expected. On a collection and photography foray to the Allegan State Game Area we did, indeed, find *Scleria reticularis.* The plants were growing on an exposed mud flat of Crooked Lake and formed a nearly solid stand of a few square meters. This Allegan County site is not a surprising one for *Scleria*, as it grows with other species having coastal plain affinities and with some of the more remarkable coastal plain disjuncts.

Crooked Lake is located on the bed of Glacial Lake Algonquin at an elevation of 670 ft. It has neither inlet nor outlet and fluctuates in depth from year to year and season to season. These changes result in a widely fluctuating shoreline and extensive mud flats during the late summer of low-water years. Lakes such as this have been termed soft-water seepage lakes by Wilson (1939) and are particularly suitable locales for some coastal plain species (Pepoon, 1927; Pierce, 1974; Sinnott, 1912). In fact, in Michigan species such as *Rhynchospora macrostachya, Psilocarya scirpoides, Fuirena squarrosa,* and *Eleocharis melanocarpa* are nearly confined to such situations.

For the wild flower enthusiast and the professional botanist alike Crooked Lake offers numerous attractions. On the lake shores are such showy species as *Xyris torta* (Yellow-eyed Grass), *Rhexia virginica* (Meadow Beauty), *Spiranthes cernua* (Ladies' Tresses), *Spiraea tomentosa* (Steeplebush), *Drosera rotundifolia* (Sundew), and *Woodwardia virginica* (Virginia Chain Fern). Associated more intimately with *Scleria* on the mud flats are *Psilocarya scirpoides* (Bald Rush), *Rhynchospora macrostachya* (Beaked Rush), and *Rotala ramosior* (Tooth Cup). On nearby sandy shores are *Panicum meridionale,*

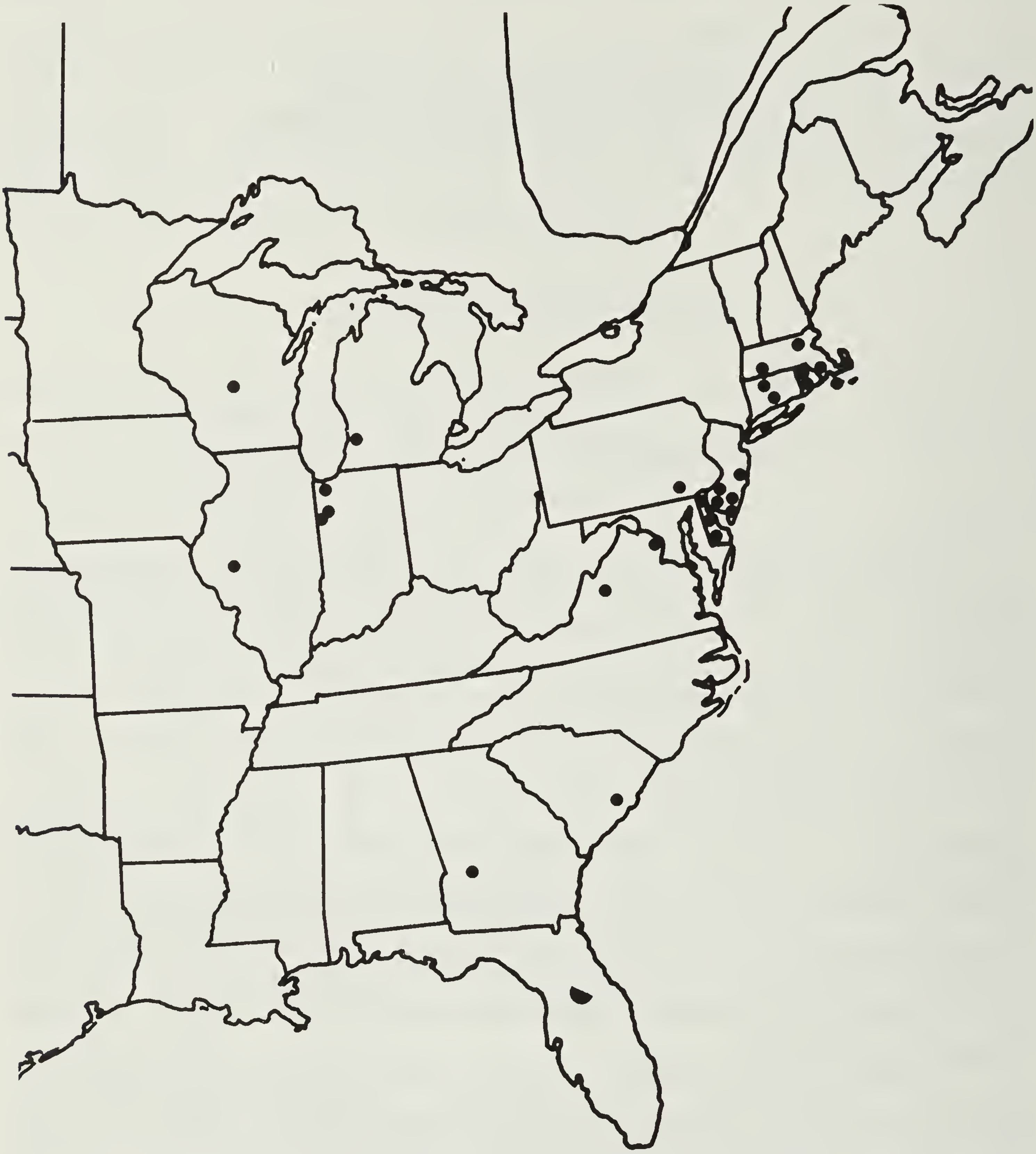

Fig. 1. Distribution of *Scleria reticularis* in the United States from Pierce (1974), compiled from herbarium records and literature accounts, especially from Core (1936). The dots refer to county records, and the half circle in Florida refers to an unspecified location.

Bulbostylis capillaris, Fuirena squarrosa (Umbrella-Grass), and *Hemicarpha micrantha.*

Here on Crooked Lake is apparently the first authentic record of *Scleria reticularis* from Michigan. Hebert (1934) reported the species from Berrien County. Voss (personal communication) has, however, examined the plant on which the record is apparently based (Michigan: Berrien Co., Dayton Swamp, *Hebert 1144*; ND) and determined that it is, in fact, a specimen of *Zigadenus glaucus. Scleria reticularis* has been reported from other midwestern locations in Indiana, Illinois, and Wisconsin, but this locale, where it is found in community with so many eastern and southern species, makes it worthy of particular mention.

Specimens of *Scleria reticularis* on which this report is based are deposited in the Hanes Herbarium at Western Michigan University (WMU) and in the University of Michigan Herbarium (MICH): Allegan County, Clyde Township, Crooked Lake, T2N, R15W, NW1/4 section 36, *Pierce 1811,* 13 Sept. 1970; *Pierce & Pippen 1834*, 17 Aug. 1971.

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DIMORPHISM IN COLLYBIA RACEMOSA

Roy Watling

Royal Botanic Garden, Edinburgh

Bryce Kendrick

Department of Biology
University of Waterloo, Ontario

The large, branched "coremia" of *Sclerostilbum septentrionale*, a hyphomycete described by Povah (1932), were found by its author springing from sclerotia among dead leaves on Isle Royale, Michigan. Povah suggested that it might be the asexual (or conidial) state of an ascomycete, possibly a species of *Xylaria*. During a survey of the conidial states of Basidiomycetes, upon which we are currently engaged, one of us (RW) found a suggestion by Singer (1951 *et seq.*) linking *Collybia racemosa* and *Sclerostilbum*. Singer, as shown by Donk (1962), relied on observations made by Lütjeharms (1934), who apparently appreciated the relationship between the two genera. Singer, however, was unsure whether the *Sclerostilbum* coremia represented conidial fructifications or early stages in basidiocarp development. Kendrick & Carmichael (1973) missed this connection in their compilation of hyphomycete genera, and there is no description elsewhere in the literature of how the mitospores of *C. racemosa* are formed.

From an examination of Povah's text and diagnosis, supported by a fragment of the type collection (MICH–Figs. 1D, 2E-I), it was possible to make a comparison with material of *C. racemosa* from Britain (*Orton 1137*) and from continental Europe (*Orton 37*), both in herb E (Figs. 1A-C, 2B-D). The collections were virtually identical in all respects but one–Povah's material had no apical cap or pileus and, therefore, no basidial hymenium. Slight differences in conidium size among the three collections were not considered significant.

Lange (1936) illustrated "headless" specimens of *C. racemosa* (just like those figured by Povah) alongside illustrations showing a fungus with all the features of a basidiomycete classifiable in the Agaricales. Lange indicated that the cap (pileus) may sometimes fail to develop; he noted that the side branches possess small "pilei," and implied that these too might remain undeveloped.

Rea (1922) incorrectly considered the branches to be simple capitate hairs with oblong, hyaline, glutinous heads.

One of us (RW) has recently examined material of *Collybia racemosa* (in K). In a packet accessioned by Crossland, about 1912, was a note from Crossland to Thwaites, who had made the collection:

> Taking the branches only into consideration apart from the central pileus the fungus would be placed in the genus *Stilbum* (hyphomycetes); the branches bear conidia at their tips, oblong-elliptic, 2 guttulate, 8-12 × 3-3.5 μm, straight or slightly incurved.
>
> The branches undoubtedly belong to the *Collybia* stem. Don't see how they can be parasitic upon it.

Crossland was clearly the first to recognize, or at any rate to express an opinion on, the unity of the conidial and the basidial states of *C. racemosa*.

It is now clear that the large "coremium" mentioned by Povah (1932) is the stalk or stipe of the agaric and that only the small side branches can be regarded as true coremia.

C. racemosa is placed in *Collybia* section *Collybia* (=*Cirrhatae* Singer) along with *C. cirrhata* (Schum. *ex.* Fr.) Kummer, *C. cookei* (Bres.) Arnold, and *C. tuberosa* (Bull. *ex* Fr.) Kumm., all of which are widely distributed in north-temperate countries, are much commoner than *C. racemosa**, and have been extensively studied by Arnold (1935).

Agarics of section *Collybia* are very frequently associated with decaying fungi, usually other agarics, but sometimes members of the Aphyllophorales.

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*The agaric figured by Brefeld (1889) as *C. racemosa* is certainly *C. tuberosa,* and his *C. tuberosa* is probably *C. cookei.*

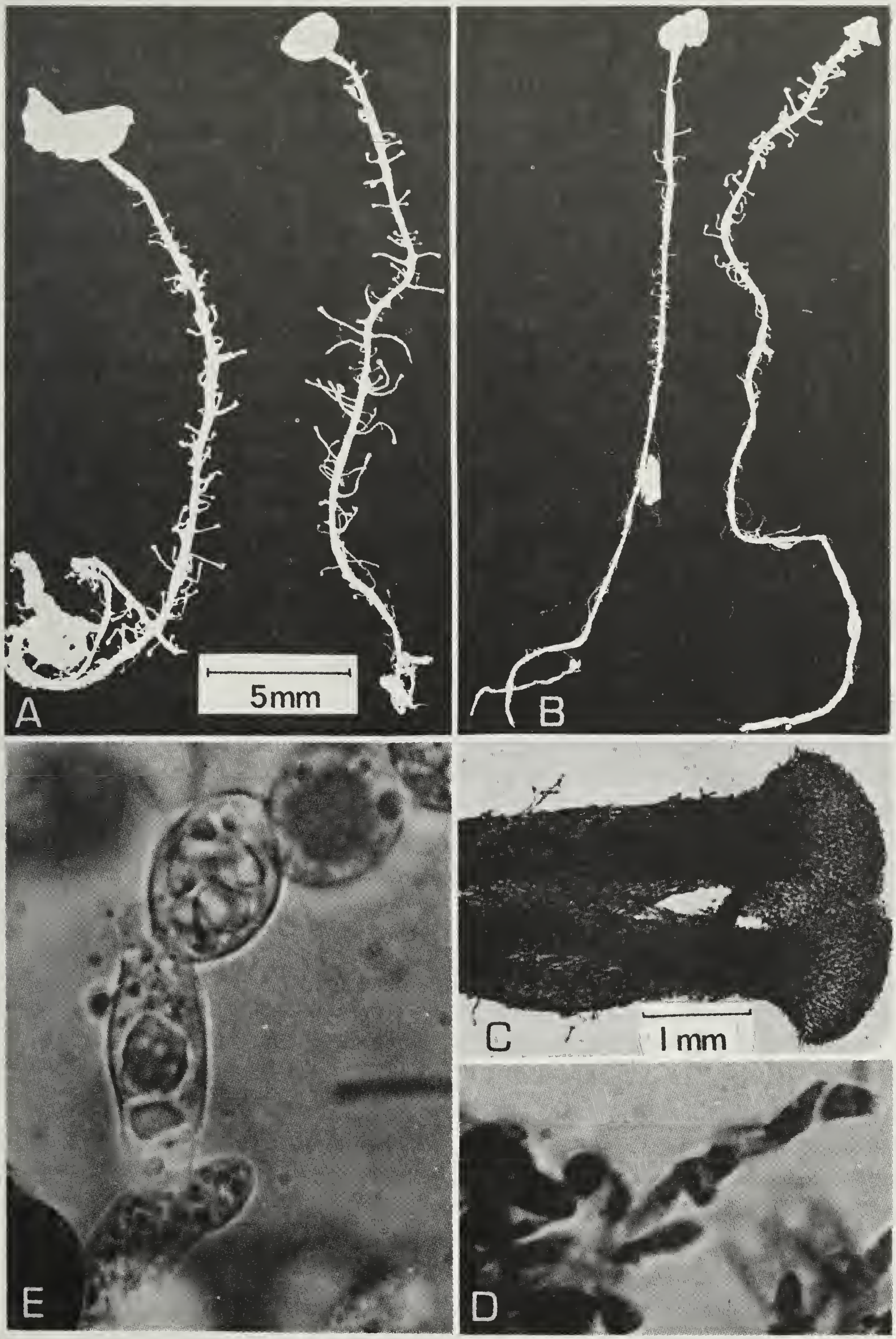

Fig. 1.A-B. Silhouettes of *Collybia racemosa* (A. Belleme, Normandy, *Orton 37*; B. Clapham Wood, Yorkshire, *Orton 1137*). C. Two coremia of *Sclerostilbum septentrionale* from B. D. Part of a coremium of *S. septentrionale* squashed to show a chain of conidia with subtending clamp connections. E. Chain of chlamydospores with clamp connections in vegetative culture of *Pleurotus dryinus (Watling 11639)*.

C. cirrhata is sometimes found where there is no evidence of the prior existence of a dead fungus. One of us (RW) has found *C. racemosa* growing in humus, but Rea (1922) and Smith (1937) recorded this species as occurring on decaying fungi.

Rea, following Quélet, described the spores of *C. racemosa* as oval and ornamented; this suggests that the ammoniogenous agaric, *Tephrocybe tesquorum* (Fr.) Moser, may in part have been confused with *C. racemosa.* Certainly *Tephrocybe* is similar in structure and general facies (although it lacks the small branches on the stipe), and it has been found on dead agarics (RW).

All species of section *Collybia* except *C. cirrhata* produce sclerotia: that of *C. cookei* is yellow to ochraceous; that of *C. tuberosa* is a dark red-brown and often resembles an apple-seed; that of *C. racemosa* is roundish and black (Fig. 2E).

Arnold induced the formation of sclerotia in cultures of *C. cookei* and *C. tuberosa* and in fact obtained mature fruit bodies from them. The sclerotia of *Coprinus sclerotiger* Watl. will germinate readily if kept in damp sand, but those of *Collybia cookei* (Bres.) Arnold studied (*Watling 17c*) remained sterile. We know little about the factors which break the dormancy of *C. racemosa* sclerotia, but we do know that the natural fruiting period is during the autumn.

The basidiome of *C. racemosa* develops directly from a sclerotium, first forming a long, dark stipe with a pale, obtuse tip resembling an erect, negatively geotropic rhizomorph of *Armillaria mellea* (Vahl. *ex* Fr.) Kumm. At apparently random areas in the cortex along the entire length of the stipe small branches push out, and in a fully elongated stipe such branches may number several score. These small branches may themselves branch, and every branch terminates in a pale, slightly swollen head which produces chains of conidia. At maturity, the apex of the main stipe swells, and a pileus differentiates, apparently in gymnocarpous fashion (Fig. 2A). This is certainly in keeping with the development of the closely related *C. tuberosa* (Reijnders, 1933). The ultimate length of the stipe on which a mature pileus develops appears to be very variable, probably depending on the size of the original sclerotium, or on the environment. This is like the phenomenon found in an unnamed Australian temperate rainforest *Mycena*, whose stipe may wind through the leaf litter for up to half a metre before forming a pileus. All four species of section *Collybia* normally form a very thin-fleshed, rather small, membranous, pale-coloured pileus. Three of the species have a finely pruinose stipe: *C. racemosa* is unique in its possession of coremioid structures arising from the stipe.

The tiny, dark side-branches of *C. racemosa* (the asexual fructifications, of a type often called synnemata or coremia) are composed of parallel, aggregated, broad hyphae with hard, glassy, fairly brittle, little-pigmented walls, and disorganized cytoplasm containing amorphous dark-coloured material. Where the coremium stalk expands into the crescent-shaped fertile head, the hyphae become thin-walled and slightly swollen, and their contents have a strong affinity for cotton blue. All hyphae are clamped, though those

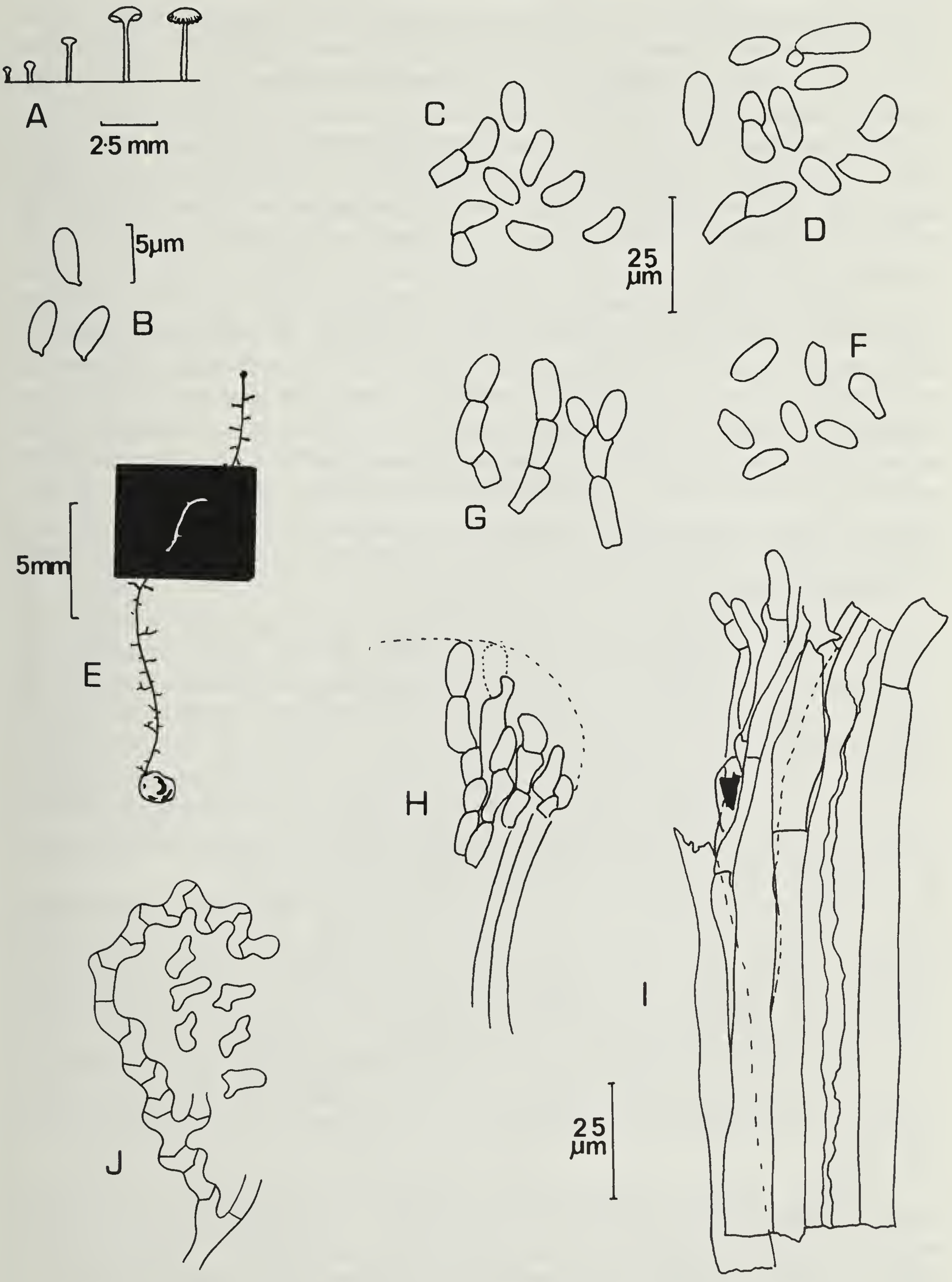

Fig. 2.A. Gymnocarpic development of *Collybia racemosa*. B. Basidiospores from *Collybia racemosa (Orton 1137)*. C-D. Arthroconidia of the *Sclerostilbum* state of *Collybia racemosa*. C from *Orton 37*; D from *Orton 1137*. E. Reconstruction of *Sclerostilbum septentrionale* with silhouette of part of the type inserted. F-I. From the type of *Sclerostilbum septentrionale* F, dissociated arthroconidia; G, arthroconidial chains in isolation; H, arthroconidal chains in coremial head; I, hyphae on cortex of coremial stipe giving rise to arthroconidia. J. *Osteomorpha fragilis* redrawn from Arnaud.

of the coremium stalk are much more sparsely septate than those in the fertile head. Some of the superficial hyphae along the side of the stalk also give rise to narrow conidiogenous hyphae. At maturity, the hyphae in the crown of the coremium cease apical growth and disarticulate across the clamps, the resulting conidia retaining the remnant of the clamp-connection as a basal and/or apical hook which may subsequently be obliterated by further swelling. Conidia apparently mature basipetally while remaining together in a linear series. They are clearly thallic-arthric conidia, as described by Hughes (1953, 1971) and Kendrick (1971a,b).

Arnold (1935) successfully obtained fruiting in pure culture, on fungal material or extract, of the three species she studied. She observed "oidia" in all three, but only on the haploid hyphae. In *C. racemosa,* haploids and diploids have not been studied, but all the basidiomes examined show clamp-connections, strongly suggesting that the dikaryon is present. Arnold recorded that the species she studied were heterothallic; *C. racemosa* probably exhibits the same pattern. Arnold gave no description of the "oidia" in sect. *Collybia,* but these would probably be similar to those of *Flammulina velutipes* (Curt. *ex* Fr.) Karsten and should be considered thallic-arthric conidia (arthroconidia).

A similar pattern of conidiogenesis to that described above for *C. racemosa*—the thallic-arthric mode—is found in the genus *Pleurotus. P. cystidiosus* O. K. Miller in culture forms coremioid structures, both on the vegetative mycelium and distributed over the maturing basidiomes. Kaufert (1935) described this fungus under the name *P. corticatus* Fr. [=*P. dryinus* (Pers. *ex* Fr.) Kumm.] and demonstrated the presence of both monokaryotic and dikaryotic coremia. Miller (1969) demonstrated the differences between Kaufert's isolate and the typical *P. dryinus,* which, though producing similar arthroconidia, does not form them on coremia (see below).

While the coremia of *C. racemosa* have dark stalks and pallid conidial heads, those of *P. cystidiosus* have white stalks and black heads which contrast vividly with the white stipe of the *Pleurotus* basidiome and so resemble the hyphomycete *Antromycopsis* Pat. & Tr., with which Jong & Peng (1975) and more recently Pollack & Miller (1976) have considered it to be connected. Singer (1975) considered these structures to be chlamydosporocarps, but the arthroconidia produced are not thick-walled. We do not know whether the thallic-arthric propagules of *P. cystidiosus* or *C. racemosa* act as spermatia.

Similar chains of thallic-arthric mitospores are produced by *Pleurotus dryinus*, but there they are not formed on coremia, and individual cells become swollen, pigmented and thick-walled—recognizably chlamydosporic (Fig. 1E). The nuclear behaviour of *P. dryinus* has been followed by Semerdzieva (1965). In *Squamanita* (Bas, 1965), hyphae covering the protocarpic bulbs form conidia, but here the growth of the hyphal tip gives rise to a sympodial arc of conidia. These conidia are well-differentiated and may be either smooth, in *S. odorata* (Cool) Imbach, or ornamented, in *S. pearsonii* Bas. *Dissoderma paradoxa* (Smith & Singer) Singer, very closely related to *Squamanita*, also possesses smooth conidia (Watling, 1974). The mitospores in *Squamanita* and *Dissoderma* are considered to be chlamydospores because the end-product is thick-walled.

Singer (1970) erected the genus *Arthrosporella* for a tricholomataceous agaric in which the conidial state is formed on a clavarioid fruit body to which the form-generic name *Nothoclavulina* has been assigned. In some individuals the apex of the clavarioid conidial fructification later differentiates into a pileus with accompanying hymenium. The genus is related to *Gerronema* and *Armillaria* (*Armillariella sensu* Singer). No definite indication is given of the mode of conidiogenesis in this fungus, but the name *Arthrosporella*, Singer's designation of the conidial fructifications as "arthrosporocarps," and the fact that some of the conidia are septate suggest that they form in true thallic-arthric manner by the fragmentation of hyphae at septa. Clamp connections are not present, and the individual conidia are reported to be uninucleate, but it is possible for dikaryotic hyphae to produce monokaryotic conidia, as in *Flammulina velutipes.*

Similar chains of conidia are found in *Ptychogaster*; these, like those already mentioned in *Pleurotus dryinus* and *Squamanita*, become thick-walled at maturity and are usually regarded as chlamydospores. Species of *Ptychogaster* are genetically connected to polypores, particularly of the genus *Tyromyces.* One of us (RW) has shown that *Phaeotrametes decipiens* (Berk.) Wright, in addition to forming basidiospores in tubes, has, on the basidiome, cup-shaped depressions lined with hyphal tips producing conidia. Conidiogenesis is similar to that in *Collybia racemosa,* though here again the mitospores of the polypore ultimately become thick-walled and distinctly pigmented chlamydospores and are not formed on coremia.

Among Arnaud's obscure genera, all unfortunately invalidly published, one finds the form-genus *Osteomorpha* (Arnaud, 1952), named from the resemblance its conidia bear to (wrist) bones. Arnaud's illustration clearly shows a closely-septate, dikaryotic hypha with a clamp connection at almost every septum. The bizarre, irregular shape of the free conidia (which would be extremely mystifying if they were to be found without the accompanying hyphae) reveals that they have been derived from the disarticulation of the hyphae across the clamp. Arnaud's illustration is reproduced here (Fig. 2J) for comparison with the cellular detail of conidiogenesis in *C. racemosa.* It is extremely unfortunate that we have no information concerning the nature of the basidiomycete whose conidial state this is.

It is interesting to speculate concerning the part played by the arthroconidia described above. Those found in the field are dikaryotic and are always formed on structures which have a much longer existence than a normal basidiome: the stipe of *C. racemosa* or the pseudosclerotial stipe-base in *Squamanita.* Species of *Pleurotus* possess woody or leathery, tough basidiomes uncommon in other agaric genera. Arthroconidia formed on specialised structures appear to be a feature of various genera within the Tricholomataceae, and if parallels can be drawn with laboratory experiments in other genera, these coremia may be even the site of a parasexual cycle.

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NOTES ON THE FLORAL BIOLOGY OF PLANTAGO IN MICHIGAN

Michael R. Mesler

Department of Biology
Humboldt State University
Arcata, California, 95521

Most species of *Plantago* produce protogynous, wind-pollinated flowers (Pilger, 1937). Individual flowers are bisexual, but the stigmas are receptive prior to pollen release. Given some asynchrony in the maturation of inflorescences among individuals of a population, this mechanism promotes (but does not insure) cross-pollination. *P. rugelii* and *P. major* exemplify this basic pollination system. Other pollination mechanisms, however, occur in the genus. For example, *P. lanceolata* produces both hermaphroditic and female flowers (gynodioecious or gynomonoecious), and outbreeding is enforced by a genetically controlled incompatibility system (Bartlett, 1911; Baker, 1963; but see Bassett, 1973). Cleistogamy, and concomitant floral reduction, has evolved independently in at least two sections of *Plantago* (Pilger, 1937). In addition, insect pollination has been reported for some species, including *P. lanceolata* (Clifford, 1962). Although Pilger (1937) described several of these modifications of the protogynous, wind-pollinated system, they generally have not been discussed in standard texts on pollination ecology (*e.g.*, Faegri & van der Pijl, 1971), and in cases where species produce both chasmogamous and cleistogamous flowers, often only one or the other form is described in state and regional floras (*e.g.*, the chasmogamous flowers of *P. virginica* are not included in Gleason & Cronquist, 1963).

The primary objective of this report is to call attention to some of the lesser known pollination mechanisms in *Plantago*. Specifically, I describe the floral biology of three species that produce both cleistogamous and chasmogamous flowers: *P. aristata* Michx., *P. patagonica* Jacq., and *P. virginica* L. In addition, I discuss the significance of insect visits to *P. lanceolata* L.

Plantago aristata, P. patagonica, and *P. virginica* were observed and collected at two localities in May and June 1974 and 1975: Camp Sequoia, Raisin Twp., Lenawee Co., Mich. and Cedar Lake, Waterloo Recreation Area, Sylvan Twp., Washtenaw Co., Mich. In addition, plants of *P. virginica* maintained in cultivation at the Matthaei Botanical Gardens by M. F. Tessene during 1967–1968 were studied. Unfortunately, the initial source(s) of the seeds for the cultures is unknown to me. *P. lanceolata* was observed in an athletic field south of Ferry Field in Ann Arbor Twp., Washtenaw Co., Mich. Distinguishing characters, phenological patterns, geographical distributions, and natural histories of these species are discussed by Pilger (1937), Salisbury (1961), Tessene (1968), and Bassett (1973).

P. aristata and *P. patagonica.* Section *Leucopsyllium* Decne.

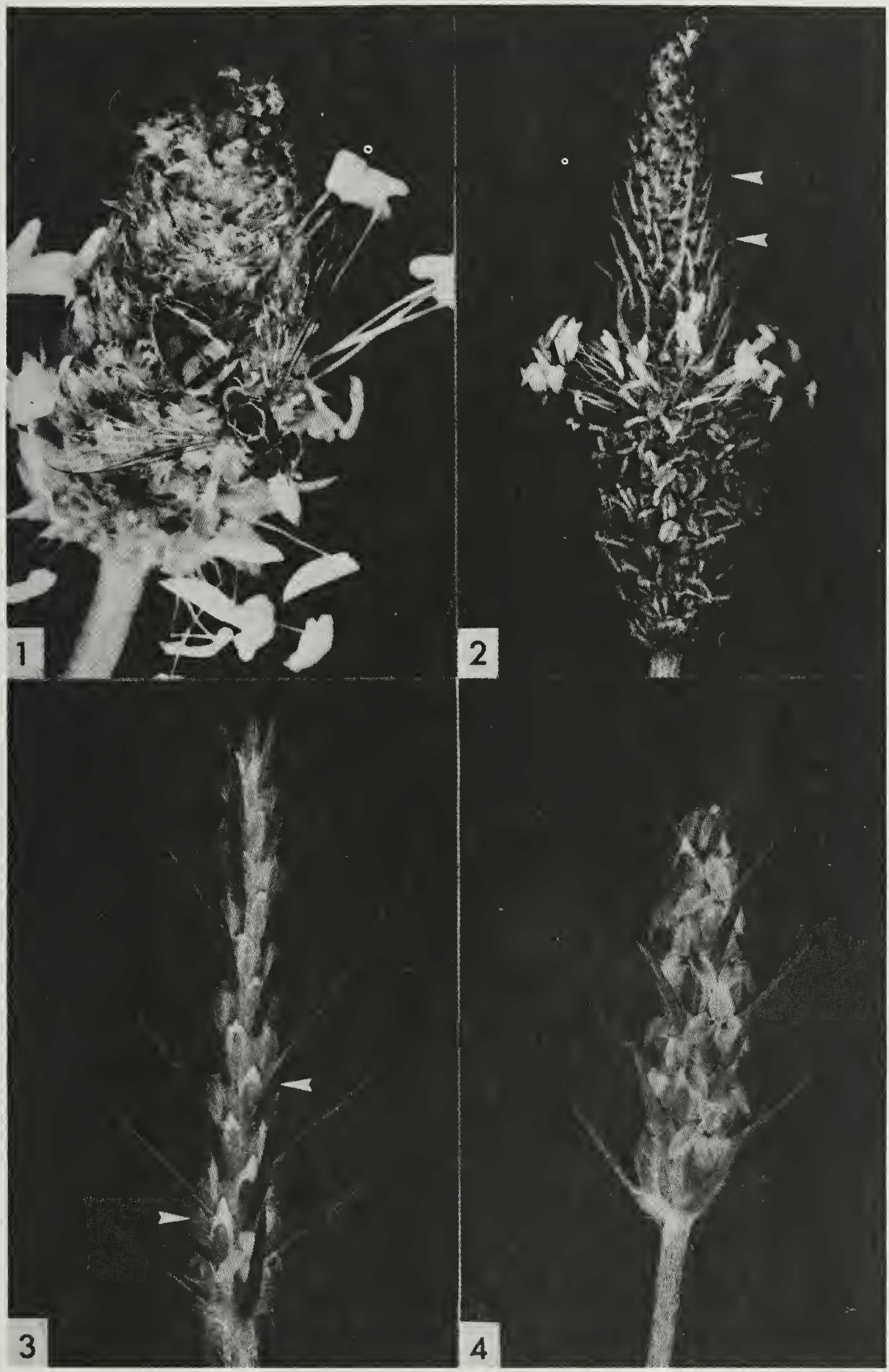
Both of these closely related species produce chasmogamous and cleistogamous flowers on separate plants. In both, the frequency of individuals that bear chasmogamous flowers is very low, but I do not have precise data. I found a total of less than 10 individuals with chasmogamous flowers in two large populations of *P. aristata* at both localities. I found no individuals of *P. patagonica* with chasmogamous flowers at either locality, but these were reported by Gray (1878). Pilger (1937) observed both types of flowers for *P. aristata.* Tessene (1968), Bassett (1973), and Gleason & Cronquist (1963) described only cleistogamous flowers for both species, perhaps because of the rareness of individuals with chasmogamous flowers. Although Bassett referred to the flowers he described as cleistogamous, Tessene and Gleason and Cronquist were apparently not aware that they were dealing with cleistogamous flowers.

In both species, the stamens of chasmogamous flowers extend well beyond the throat of the corolla at anthesis. Anthers are approximately 1 mm long, versatile, and contain numerous pollen grains. Anther dehiscence occurs only after the corolla lobes open; no pollen was observed on the lower part of the stigma juxtaposed to developing anthers before anthesis. The stigmas extend 1–1.5 mm beyond the throat of the corolla tube after the lobes of the corolla open. They are not exposed until this time, and the flowers are therefore not markedly protogynous as in other species of *Plantago.*

The corollas of the cleistogamous flowers of both species open in the same manner as the chasmogamous flowers (Fig. 4). In the cleistogamous flowers, however, the anthers dehisce before this occurs (Fig. 3), and pollen is deposited on the lower part of the stigma. Pollen tubes were observed on enclosed stigmas from one to two days before "anthesis." Anthers are 0.3-0.5 mm long, basifixed, and contain approximately 16-20 grains (Bassett, 1973). After pollination occurs and the corolla lobes open, the anthers and stigma are positioned at or just above the level of the throat of the corolla tube (see Tessene, 1968, fig. 5D,E). Some pollen is still present in the anthers at this time; this probably accounts for insect visits to *P. aristata* observed by Tessene (1968).

P. virginica. Section *Novorbis* Decne.

This species also produces chasmogamous and cleistogamous flowers (Gray, 1878; Tessene, 1968) typically on separate plants, but I have observed inflorescences with both types of flowers as well as some intermediate types (see Tessene, 1968). Individuals that bear cleistogamous flowers apparently predominate throughout most of the range of the species. Only cleistogamous flowers (not designated as such) are described in several manuals (Deam, 1940; Steyermark, 1963; Gleason & Cronquist, 1963; Correll & Johnston, 1970). The chasmogamous flowers are either absent from the regions covered by these manuals or, more likely, have been overlooked owing to rareness. In contrast, Radford *et al.* (1964) described only chasmogamous flowers for the Carolinas. In Michigan, fewer than 10 individuals with chasmogamous flowers



Figs. 1-4. *Plantago lanceolata* and *P. aristata*. Syrphid fly (*Mesograpta marginata*) probing anther of *P. lanceolata*. ×5. 2. Inflorescence of *P. lanceolata*. Flowers on upper half of spike in female phase. Note progressive extension of stigmas as flowers mature (arrows). ×2. 3. Cleistogamous flowers of *P. aristata* (arrows) before opening of corolla lobes but after dehiscence of anthers. ×2. 4. Cleistogamous flowers of *P. aristata* after "anthesis." ×2.4.

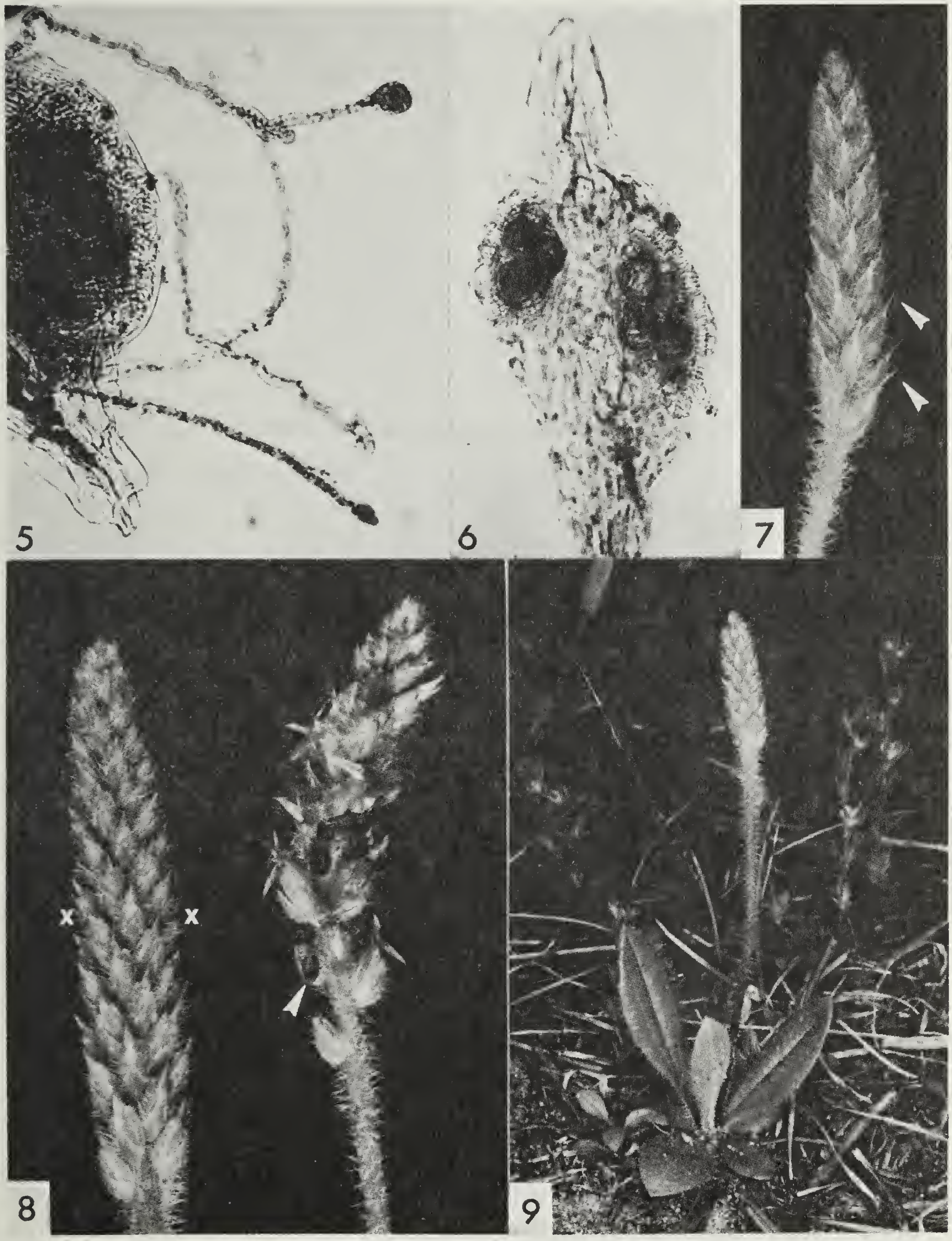
were discovered at the Lenawee Co. locality in 1974. The next year I could find no chasmogamous flowers at the same locality. Flats of *P. virginica* grown at the Matthaei Botanical Garden in 1967 consisted almost entirely of plants with cleistogamous flowers for most of the year. Occasionally, however, individuals with chasmogamous flowers dominated the cultures. The factors controlling the relative frequency of the two flower types are not known.

The chasmogamous flowers of *P. virginica* resemble the flowers of most species of *Plantago*. They are protogynous and wind-pollinated. The stigmas extend beyond the erect lobes of the corolla prior to anthesis, and after the lobes open, the stamens extend approximately 3-4 mm beyond the throat of the corolla tube (Fig. 8; see Tessene, 1968, fig. 5C'). The relatively large (0.7-1.0 mm long), versatile anthers are longitudinally dehiscent and release numerous pollen grains. Several authors have reported reduced seed production by the chasmogamous flowers (Pilger, 1937). They have been described as substerile (Gray, 1878), sterile (Fernald, 1950), or staminate (Small, 1933), but without supporting documentation. I have no data to support or refute these claims. Nevertheless, the possibility that chasmogamous forms occur commonly or perhaps exclusively in the Carolinas leads me to suspect that they are fertile in at least some parts of the species' range.

Unlike *P. aristata* and *P. patagonica*, the corolla lobes of the cleistogamous flowers of *P. virginica* remain erect and closed (Fig. 7-9; see Tessene, 1968, fig. 5C). Although the stigmas are usually completely enclosed within the corolla, in some cases their tips are exposed before self-pollination (Fig. 7). The stamens, on the other hand, are never exposed. The filaments are short, and the anthers are positioned near the base of the stigma. The anthers are very small (0.2-0.3 mm long), translucent light-green, and basifixed. Each anther contains 16 or fewer pollen grains (Fig. 6), and in some only one of the two anther sacs is fertile. Although, as observed by Pilger (1913), an endothecial layer does develop, the anthers do not dehisce. Initially the anthers do not contact the stigma, but in older flowers they become attached to the stigmatic papillae.

In some flowers with reflexed corolla lobes, two stamens with large, dehiscent anthers were exserted, whereas the other two bore smaller, non-dehiscent anthers and were included in the corolla tube. These flowers can be regarded as intermediates between typical chasmogamous and cleistogamous flowers and were only observed on inflorescences with both of these other types present.

Ludwig (1880) studied the cleistogamous flowers of *P. virginica* and concluded that the small anthers contain a small number of viable pollen grains. These germinate in the anther sacs and send pollen tubes directly to the stigma. Later, Pilger (1913) examined cleistogamous flowers of this species but could not observe pollen tubes. On the basis of this and on observations of nucellar embryony in a related species, *P. hirtella*, he concluded that seed production in section *Novorbis* (including *P. virginica*) was apomictic. Tessene (1968), impressed by the reduced, "abortive stamens and styles," came to the same conclusions. However, my observations confirm Ludwig's earlier conclusions. Pollen grains are viable (as determined by shape and positive staining



Figs. 5-9. *Plantago virginica.* 5. Pollen tubes growing from anther of cleistogamous flower. Specimen stained with cotton-blue. ×350. 6. Anther from cleistogamous flower. Three pollen grains in left anther sac, four in right anther sac. Specimen stained with cotton-blue. ×325. 7. Inflorescence bearing cleistogamous flowers with exserted stigmas (arrows). ×2. 8. Cleistogamous (left) and chasmogamous (right) flowers. Arrow indicates anther of chasmogamous flower. x–x indicates level on inflorescence corresponding to growth of pollen tubes. ×2.5. 9. Habit of plant with cleistogamous flowers. ×1.

with cotton blue) and do germinate in the anther sacs. The pollen tubes grow through the walls of the anther (Fig. 5) and into the stigma. This accounts for the attachment of the anthers to the stigmatic papillae of older flowers. Other instances of germination of pollen grains *in situ* have been reported in cleistogamous flowers of *Viola* (Madge, 1929) and some species of Malpighiaceae (W. R. Anderson, pers. comm.).

Therefore, at least as indicated by the development of the androecium, seed production in cleistogamous flowers of *P. virginica* appears to be sexual. Other studies will be needed to prove that seed production is sexual and not apomictic (*i.e.*, emasculation experiments and studies of embryo sac and embryo development). It is interesting to note that Schürhoff (1924), at the suggestion of Pilger, re-examined the embryo development of *P. hirtella* and found no evidence of nucellar embryony.

Breeding systems of *P. aristata, P. patagonica,* and *P. virginica*

Plantago aristata, P. patagonica, and *P. virginica* are annuals (rarely biennials), inhabit ephemeral, disturbed habitats, and have a broad geographic distribution (Tessene, 1968; Bassett, 1973). All three are predominantly self-pollinated, with the possible exception of *P. virginica* in the Carolinas. Theoretically, this breeding system should result in a high degree of genetic uniformity. Several authors (Stebbins, 1950; Allard, 1965; Baker, 1965) have discussed the adaptive advantages of autogamy for annual weeds: single seed required for colonization of new areas, potential for rapid increase in population size, guaranteed seed production, etc. Although these three species are predominantly autogamous, they produce a small number of chasmogamous flowers, thereby providing the opportunity for cross-pollination and genetic recombination. Exposure of the stigmas in cleistogamous flowers of *P. virginica* before self-pollination creates additional opportunities for out-crossing. Allard & Hansche (1965) have shown that a significant amount of recombination can occur in even predominantly autogamous species given some degree of heterozygote superiority. For such a species this may allow the evolution of variants adapted to local conditions over an extensive geographic range. Thus, the breeding systems of *P. aristata, P. patagonica,* and *P. virginica* could be viewed as an evolutionary compromise between the demands of immediate fitness and heterogeneous environment. Alternatively, the amount of genetic variability generated by the chasmogamous flowers may be insignificant. In such a case, the low frequency of chasmogamous flowers could be attributed to an as yet incomplete shift from chasmogamy to cleistogamy. Predictions based on either hypothesis could be tested by analyzing intra- and interpopulation variability.

Insect pollination of *P. lanceolata*

The foraging behavior of flower-visiting insects is opportunistic: *i.e.*, insects exploit any accessible food source with the constraint that foraging does not result in an overall energy deficit (Heinrich & Raven, 1972). Consequently, a direct co-evolved relationship between flower visitor and floral adaptation may not exist. A prime example is the phenomenon of nectar robbing. Another involves visits by pollen-eating insects to typically anemophilous species such as amentiferous trees, grasses, and species of *Plantago* (Beal, 1880; Chambers, 1945; Porsch, 1956; Bogdan, 1962; Clifford, 1962; Pojar, 1973; Ponomarev & Kolesnik, 1974). Although numerous reports of such visits exist, most simply include lists of species and do not consider the actual effectiveness of the insects as pollen vectors nor the possible evolutionary significance of the interaction. In this section, I briefly consider these questions with regard to insect visits to *P. lanceolata.*

Syrphid flies, halictid bees, bumblebees, and honeybees were observed visiting and foraging for pollen from *P. lanceolata* on several days in June and early July 1975. The visits of all these insects resulted in some pollination: all exhibited relatively constant foraging patterns, all contacted receptive stigmas, and pollen grains were observed on the bodies of all. The bees carried more pollen and were, therefore, probably more effective pollinators than the flies.

On clear days, visitors to *P. lanceolata* began foraging during early morning hours when atmospheric conditions were calm (6:30–7:30 A.M.). This corresponds to a stage of flower development after anther dehiscence but before dispersal of pollen by wind. Contrary to the statement by Percival (1965, p. 56), pollen remains in the anthers (and is therefore available to insects) until removed by wind action. Soon after wind velocities reach the threshold for pollen dispersal most of the pollen is released, with the exception of a few grains that remain lodged within the anthers for the remainder of the day.

The syrphid fly *Mesograpta marginata* (Say) was the most commonly observed visitor to *P. lanceolata* (Fig. 1). This species is abundant in fields and dooryards around Ann Arbor, and hundreds were observed daily in the study area. Individuals commonly begin foraging when ambient air temperatures are low, suggesting some measure of endothermy (see Heinrich, 1975). Foraging continues until just before sunset, although fewer flies were observed on *Plantago* later in the day, presumably because of a reduced amount of available pollen. The flies forage at one or more flowers on an inflorescence before moving on to the next inflorescence (on the same or a different plant). They do not visit flowers in rapid succession; foraging is interspersed with mating behavior (particularly early in the day), and many were observed sitting on foliage (increasing body temperature by basking?). Nevertheless, individual flies that were followed for several minutes confined their visits almost exclusively to *P. lanceolata* and only rarely visited such potential nectar sources as *Convolvulus arvense* and *Polygonum aviculare.*

According to Oldroyd (1964), adult syrphids feed exclusively on nectar and honeydew, and protein procurement occurs only during the larval stage of the life cycle. However, pollen grains contain relatively large amounts of protein, as well as fats and carbohydrates (Faegri & van der Pijl, 1971), and pollen feeding by adult syrphids was observed by Müller (1883) and E. & H. Drabble (1927; see also Baker & Baker, 1973). The following observations indicate that adults of *M. marginata* eat the pollen of *P. lanceolata*. Individuals repeatedly probed anthers with their proboscises while on the flowers. In addition, they apparently distinguished between anthers with relatively large and small amounts of pollen and spent considerably less time at poor pollen sources. On one cool morning, when flies could be captured by hand relatively easily, a tiny drop of fluid was observed at the tip of the proboscis of a fly removed from a flower while feeding at an anther. Based on the work of Müller (1883) and Becher (1882), Proctor & Yeo (1973) concluded that syrphids ingest pollen grains suspended in saliva that is exuded at the tip of the proboscis and then sucked back into the mouth. It appears that *M. marginata* ingests pollen grains in this way and that at least some protein is obtained during the adult phase of the life cycle.

The most common of the bee visitors to *P. lanceolata* were small, unidentified halictids. Like *M. marginata,* they were observed foraging from early morning until early evening (*ca* 7:00 P.M.) but were considerably less common at the end of the day. Foraging bees were abundant in the immediate vicinity of their nests but were less widespread at the study site than the syrphids. Individuals that were followed limited their foraging to *P. lanceolata* and visited several plants in succession. Constant foraging behavior was confirmed by examination of pollen loads from the hind legs of the insects. These consisted entirely of *P. lanceolata* pollen. The bumblebees and honeybees that visited *P. lanceolata* also exhibited constant foraging patterns but were observed only during early morning hours (never after 11:00 A.M.) when maximum amounts of pollen were available in the anthers. They flew rapidly between plants and spent only a few seconds on each inflorescence.

The flowers of *P. lanceolata* are well adapted for wind pollination (Proctor & Yeo, 1973), a fact underscored by the large numbers of plantain pollen grains caught in atmospheric pollen analyses (Hyde, 1950). Nevertheless, insects can be effective pollinators. What then is the evolutionary significance, if any, of insect pollination of *P. lanceolata*? Is there any evidence of adaptations that would promote insect visitation? These questions are complex and difficult to answer. For example, insects were rarely observed visiting *P. rugelii*, a species often sympatric with *P. lanceolata* but with much smaller and less conspicuous anthers. Greater anther size in *P. lanceolata* could be regarded as an adaptation to promote insect *or* wind pollination, or possibly both.

One way to evaluate the significance of insect pollination would be to determine the amount of pollination that occurs by wind alone. Selection for insect pollination would be expected only if wind pollination does not result in a high percentage of seed set. Since *P. lanceolata* is gynodioecious, I could test the effectiveness of wind pollination. Female flowers have relatively inconspicuous, yellow-green anthers and are not visited by insects; therefore, any pollen present on the stigmas of these flowers can be assumed to have been transported by wind. Only some of these grains will be effective, however, owing to the genetic incompatibility system of the species. Since genetic basis of self-incompatibility in *P. lanceolata* is not known, the exact proportion of illegitimate (incompatible) grains/stigma cannot be estimated but should be inversely related to the number of alleles involved in the system. I examined 113 stigmas from 15 female plants for pollen, with the following results:

Number of grains	Number of stigmas	Percentage of total number of stigmas
0	6	5%
1	18	16%
2-5	42	37%
6-10	21	18%
11-15	11	10%
16 or more	15	13%

Two ovules are present in each ovary of *P. lanceolata.* Therefore, approximately 79% of the sample stigmas bore pollen loads sufficient for complete seed production. These results should be regarded as a conservative estimate of the efficacy of wind pollination. Stigmas are exposed for more than a single day (Fig. 2), and so more pollen should be present on relatively old stigmas. Unfortunately stigmas of all ages were included in the sample; a more accurate estimation would have been obtained if only relatively old stigmas had been examined.

It appears that under the conditions prevailing at the study site and throughout most of the range of *P. lanceolata* (*i.e.,* relatively open habitats with closely spaced individuals), there is little or no contemporary driving force for evolutionary change toward insect pollination. In other situations where individuals are more widely spaced or where climatic conditions are not favorable for wind pollination (see Pojar, 1973), selection of characters that promote insect pollination can be envisioned. Evolution toward entomophily has occurred in the genus. *Plantago media*, like *P. lanceolata*, is both wind and insect pollinated but, unlike *P. lanceolata*, it has some floral characters that are best explained as insect attractants: *viz.*, fragrant flowers, purple filaments, white or lilac anthers (Harms & Reiche, 1895; Clapham *et al.*, 1962; Tessene, 1968).

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EXTENT OF VEGETATIVE REPRODUCTION IN ELEVEN SPECIES OF SPHAGNUM FROM NORTHERN MICHIGAN

David M. Lane

Department of Botany, Duke University,
Durham, North Carolina, 27706

It is commonly thought that the clumps of *Sphagnum* arise, for the most part, from repeated branching of stems. This opinion prevails in spite of the fact that many species fruit abundantly and presumably release large numbers of spores, though the protonema resulting from spore germination has been rarely observed in the field. Large clumps of a single species are often referred to as colonies, and it is assumed that each colony is clonal. Clones of *Sphagnum* species could arise by any of several means of vegetative or asexual reproduction. Although the morphology of asexual reproduction has been under study since Schimper's time (1848), the significance of vegetative reproduction has seldom been emphasized.

Three questions then arise. Can examples of vegetative reproduction be found in the field? Are there differences in extent of vegetative reproduction between different species? Can any differences in extent of vegetative reproduction be related to the growth form and habitat of the different species? The present study attempts to investigate these questions, the answers to which would contribute to the taxonomy, ecology, and horticultural use of *Sphagnum*.

To determine the extent of vegetative reproduction in species representative of different habits and habitats, intensive or mass samples were collected, sorted, and counted. Species were selected by several criteria: Each species should be available in large, nearly pure stands. Each species should be relatively near other selected species in the same general habitat to minimize environmentally induced variation. The habitat for each species should be typical, and at a documented station where the species is abundant. The species should be collected in as large a sample as possible with minimum disturbance to the easily broken stems.

Eleven species in all were collected from four sites. *Sphagnum recurvum* was collected from two sites. *Sphagnum centrale, S. girgensohnii, S. recurvum, S. warnstorfii,* and *S. wulfianum* were collected north of an east-west gravel road on the north shore of Burt Lake, about two miles south of the University of Michigan Biological Station in the *Thuja* swamp known locally as Reese's Bog (Cheboygan Co.). *Sphagnum capillifolium, S. cuspidatum, S. fuscum, S. magellanicum,* and *S. recurvum* were collected in a large hummock-hollow complex in an area known as Stutsmanville Bog just southeast of Stutsmanville (Emmet Co.). *Sphagnum teres* was collected at the edge of a floating mat on the south margin of Mud Lake Bog in Inverness Township (Cheboygan Co.). A rare species, *S. riparium,* locally abundant in Bryant's Bog on the south shore of Douglas Lake (Cheboygan Co.), was also collected.

The general ecology of these and other bogs in northern Lower Michigan is detailed in Gates (1942). Documentation and ecological studies of the *Sphagnum* species at these sites are presented in Vitt, Crum & Snider (1975). The long-term history of Bryant's Bog, in particular, is covered in Schwintzer & Williams (1974). A more encompassing study of *Sphagnum* ecology in relation to environmental gradients was published by Vitt & Slack (1975). An overview of *Sphagnum* and other aquatic bryophytes in the context of limnological botany is given in Hutchinson (1975). Identification of collections was carried only to the species level and follows Crum (1976).

Each species was collected with a hand trowel in .09 m^2 samples and lifted onto cardboard sheets (ventilators) or into plastic dishpans and wrapped moist in a plastic bag for immediate sorting or allowed to dry out for sorting at a later time. Once dried out, *Sphagnum* is easily restored by wetting with boiling water. The details are given here as precautions necessary to preserve the fragile habit of some species on the one hand and (by drying) to prevent rapid etiolation on the other.

Each species was sorted by hand into the following categories of vegetative reproduction: stems without dichotomies, stems with one dichotomy, stems with more than one dichotomy, so-called "juvenile forms," and innovations. The "juvenile forms" may not necessarily be in a younger stage of growth, but are only of smaller size and reduced morphology. The terms 'simplex' and 'subsimplex' have been used by Andrews (1960), among others, for stems without or with only a few branches. Innovations, or new plants arising from fragments of old plants, were observed in some species.

The most common type of innovation noted was juvenile forms connected to a piece of stem at the place of a branch in a fascicle. In six species–*Sphagnum centrale, S. warnstorfii, S. girgensohnii, S. magellanicum, S. teres,* and *S. cuspidatum*–innovations appeared to arise from the branch cortex at the side of a branch leaf. Though multiple stem innovations, or several on one stem, were common, no multiple branch innovations, or several on one branch, were observed.

After sorting, the individuals were counted and the following data recorded for each species collected: number of mature capitula, number of dichotomies, number of juvenile forms, and the number of innovations. The very high numbers of juvenile forms and innovations in *Sphagnum cuspidatum* were estimated by subsampling a portion (about 25%) of the collection and then multiplying by a factor (about four) to arrive at an approximate number.

The distance between successive multiple dichotomies was measured to the nearest centimeter. Often the two stems of a dichotomy were noted to be of unequal length. The mean distance and standard error of the mean were then calculated.

Data are presented in Table 1. If the number of mature capitula, juvenile forms, and innovations are added together to give the total number of apices counted, that number is 19,426. The results that follow, then, are based on a total sample size of nearly 20,000 individuals covering a total area of only a little over one (1.08) square meter, indicating a surprisingly high density.

To compare the extent of vegetative reproduction in each species, the number in each category was divided by the total number of apices counted for that species and expressed as a percentage. A crude measure of growth was also calculated by dividing the number of dichotomies by the number of mature capitula less the number of dichotomies and expressing the result as a percentage. In other words, the increase in capitula due to dichotomizing was calculated as a percentage. These results are shown in Table 2. Note that *Sphagnum recurvum* has low percentages in each category that are similar, if not identical, for both of the habitats it was collected in. The extent of vegetative reproduction may be characteristic of certain species.

To facilitate generalizations about the genus as a whole from the 11 species selected, the overall mean, standard deviations, and standard error of the percentages (in each vegetative category) from Table 2 and the distances between dichotomies from Table 1 are shown in Table 3. All together, the various categories of vegetative reproduction make up about one third of the growing points in a *Sphagnum* clump. Examples of dichotomies, juvenile forms, and innovations, therefore, can easily be found in the field. The number of innovations, though, is consistently small. Large clumps may indeed arise by various means of vegetative reproduction over a long period of

TABLE 1. Numbers in each category of vegetative reproduction.

Species	mature capitula	dichotomies	juveniles	innovations	distance between dichotomies mean (cm)	std. error
S. capillifolium	1487	262	2	2	4.5	.83
S. centrale	885	243	15	52	5.3	.85
S. cuspidatum	1755	21	c.2340	c.92	––	––
S. fuscum	2312	435	101	23	2.2	.40
S. girgensohnii	760	269	85	19	4.6	.64
S. magellanicum	745	194	121	24	2.0	.22
S. riparium	1076	130	585	4	3.4	.67
S. recurvum:						
Thuja swamp	1186	121	63	1	4.0	0
hummock-hollow	1653	94	83	1	––	––
S. teres	1519	47	342	5	.5	0
S. warnstorfii	1366	275	302	39	4.6	.67
S. wulfianum	381	166	0	0	5.1	.61

time. A large clump in the field, however, cannot be shown to be clonal in origin, at least at any given time.

The overall percentage of dichotomies is less than one fifth, even though the mean distance between successive dichotomies is less than the length of most intact stems. In other words, throughout the entire green portion of the stems and the intact part of the decaying brown portion beneath it, a distance of a decimeter or more, the extent of dichotomous branching is low.

If the growth rate of all stems in a clump were equal, and dichotomies were produced at the same time every year, so that the distance between dichotomies was a few centimeters, then the percentage of dichotomies in stems of a decimeter or more in length should be significantly higher than that observed. Clymo (1970) has proposed a theory that the environment controls growth rate to the extent that few capitula grow above or below an overall level at the surface of a clump. That the growth rate is not equal for all stems, however, is shown by the presence of dichotomies which have two stems of unequal length. This may be a result of unequal depression under the weight of winter snow. Even if the growth rates were similar, but not equal, and dichotomies were produced at different times every year, the distances between dichotomies would be expected to be similar. This was not observed to be so. The distances between dichotomies varied greatly, ranging from a few millimeters to 18 centimeters in *S. girgensohnii.* It seems unlikely that each capitulum produces a dichotomy at about the same time every year. Nevertheless, the many stems observed with dichotomies within the capitular region would seem to indicate that a small percentage of the capitula in large clumps dichotomized the year of collection.

Several species listed in Table 2 have percentages near or outside the standard deviations listed in Table 3. *Sphagnum wulfianum* is unique with 44% dichotomies and no observed juvenile forms or innovations. This rare species grows erect in open clumps usually over decayed logs in *Thuja* swamps. *Sphagnum wulfianum* appears to have dichotomous branching as an exclusive means of vegetative reproduction.

TABLE 2. Percentages of each vegetative category and of crude growth.

Species	Dichotomies	Juveniles	Innovations	Growth
S. capillifolium	18	1	1	20
S. centrale	26	2	6	39
S. cuspidatum	1	56	2	1
S. fuscum	18	4	1	23
S. girgensohnii	31	10	2	57
S. magellanicum	21	14	3	35
S. riparium	8	35	1	14
S. recurvum:				
Thuja swamp	10	5	1	11
hummock-hollow	5	5	1	6
S. teres	3	16	1	3
S. warnstorfii	16	18	2	24
S. wulfianum	44	0	0	60

TABLE 3. Overall statistics for the 11 *Sphagnum* species selected.

Category	Mean	Standard deviation	Standard error
% dichotomies	16.7	12.7	3.7
% juveniles	13.8	16.6	4.8
% innovations	1.5	1.7	.49
distance (cm) between dichotomies	3.6	1.6	.50

In contrast, two species, *Sphagnum recurvum* and *S. teres*, known for their loose habit of growth, have low percentages of dichotomies and so could therefore be sorted easily. *Sphagnum cuspidatum* is unique for two reasons. First, it has a very loose habit associated with floating in water in hollows. Like *S. recurvum* and *S. teres, S. cuspidatum* has very few dichotomies. This fact leads to the inference that there is a relation between habit and percentage of dichotomies. Secondly, the *Sphagnum cuspidatum* collected contained a large number of juvenile forms as short as a centimeter. This species appears to have juvenile forms and innovations as primary means of asexual reproduction. Another species rare to this area, *S. riparium*, that tends to grow in wet hollows or depressions, also has a high percentage of juvenile forms. This would indicate a relation between habitat and percentage of juvenile forms. That the means of vegetative reproduction may be related to both habit or growth form and habitat may explain further the correlations, first recognized by Gimingham & Birse (1957), between growth form and habitat of bryophytes, in general.

One test of the hypothesis that the primary means of vegetative reproduction is related to habitat is whether there is a change in primary means in *Sphagnum* species distributed over hummock-hollow complexes. In Table 4, the species involved and the percentages in each category are arranged in the idealized sequence from low hollow species, *S. cuspidatum,* to hummock top species, *S. fuscum,* at the top of the column. Correlated with this series are gradients, respectively, from wet to dry moisture content, relatively low to high acidity according to Vitt, Crum & Snider (1975), and loose to tight, even compact habit. Included in Table 4 is a rough measure of density or number of apices per square decimeter. There appears to be a shift in primary means from juvenile forms to dichotomies from hollow to hummock species. From the one intensive sample of each species, the rough

TABLE 4. Percentages in each category and rough density of hummock-hollow species arranged from hummock-top species (*S. fuscum*) to hollow species (*S. cuspidatum*).

Species	% dichotomies	% juveniles	% innovations	Density (apices/dm^2)
S. fuscum	18	4	1	271
S. capillifolium	18	1	1	166
S. magellanicum	21	14	3	99
S. recurvum	5	5	1	193
S. cuspidatum	1	56	2	465

measure of density tends to be highest for the hollow species and the hummock top species and tends to decrease in between. (More definitive information will be available when work in progress by Dr. Jerry A. Snider and Dr. Howard Crum is completed.)

The answer to all three questions posed at the beginning, then, is in the affirmative. Examples of vegetative reproduction can be found in the field. There are differences in extent and means of vegetative reproduction between species. Differences in primary means of vegetative reproduction can be related to habit and habitat of the species.

Several questions remain, however. What is the origin of the so-called juvenile forms? Do they represent innovations from stem or branch or, as Smith (1938) stated, growth at the tips of ascending fasciculate branches? Or, are they indeed juvenile stems produced from protonemata? Or, do they arise, sometimes, through regression of the mature capitulum caused, perhaps, by self-shading? Such a process could account for the few juvenile forms observed with mature fasciculate branches below.

This method may be appropriate for studying other bryophytes, particularly mosses that form extensive clumps. The extent of vegetative reproduction is but one aspect of the larger field of population dynamics or plant demography (Harper & White, 1974). A final question, then, is whether the admittedly laborious method of intensive sampling, sorting, counting, and simple statistical analysis is the most revealing.

SUMMARY

Mass samples of 11 species of *Sphagnum* collected in northern Lower Michigan were sorted, counted, and analyzed by simple statistics to determine the extent of vegetative reproduction. From a total sample of nearly 20,000 apices representing a total area of about one square meter, three means of vegetative reproduction were identified: dichotomous branching of the stem, juvenile forms, and stem and branch innovations. The percentage of each category of the total number of growing points was calculated and compared by species, habit, and habitat. The exclusive means of the rare *S. wulfianum* which grows in erect clumps was dichotomous branching. Species known to have loose habits, *S. recurvum* and *S. teres,* were found to have few dichotomies. Species growing in wet hollows, *S. cuspidatum* and *S. riparium*, tended to have juvenile forms as a primary means of asexual reproduction. A shift from juvenile forms to dichotomous branching as a primary means was noted along the gradients of environmental factors from hollow to hummock species, respectively. Several lines of evidence make it unlikely that *Sphagnum* capitula all dichotomize every year. The origin of 'juvenile forms' remains in question.

This study was carried out as a special problem under the direction of Dr. Howard Crum at the University of Michigan Biological Station during the summer of 1976. Assistance in the field and helpful criticism given by Dr. Jerry A. Snider, Ann Rushing, Ann Stoneburner, and Jeffrey Holcombe are gratefully acknowledged.

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REVIEWS

SPRING FLORA OF WISCONSIN. By Norman C. Fassett. 4th ed., revised and enlarged by Olive S. Thomson. University of Wisconsin Press, Madison. 1976. 413 pp. $3.95, paper cover; $8.50 clothbound.

The long-awaited new edition of this exemplary spring flora finally became available the middle of last spring. (The publication date stated with review copies, October 27, 1975, contradicts both the facts and the copyright.) More than doubled in size (yet scarcely increased in price!), the new flora practically makes one want to teach a spring course in taxonomy in order to be able to use it. Certainly every field naturalist in the Great Lakes region will want to own a copy, with its usable keys, illustrations, and enlarged glossary (mostly a good one, although the adjective "zygomorphic" is not a "type of symmetry" and any difference between "upper half and lower half" of a flower is beside the point of bilateral symmetry).

Some genera and families avoided in previous editions account for the bulk of the enlargement: James H. Zimmerman has contributed 4 genera of Cyperaceae, including 12 species of *Scirpus* and 122 of *Carex,* and 5 species of *Juncus;* H. A. Davis, A. M. Fuller, and T. Davis contributed 37 species of blackberry (erroneously called subgenus *Eubatus* [it should be subgenus *Rubus*]); and 22 species of *Salix* follow the work of George Argus. Other general enlargements involve *Quercus, Rumex, Rosa,* and *Viola* (following N. H. Russell). Certain species (such as *Sisyrinchium farwellii*) have presumably been added because of recent recognition in Wisconsin; others, because of recognition that they may bloom before the June 15 cutoff date for the spring flora. Families newly appearing in this edition, as a result, include Sparganiaceae, Juncaginaceae, Butomaceae, Capparidaceae, Resedaceae, and Lobeliaceae. Among the many newly admitted species are *Convallaria majalis, Smilax illinoensis* (said to be a hybrid but without the hybrid symbol before the epithet–which is where it belongs, e.g., *Lonicera* ×*bella,* not × *L. bella*), *Erucastrum gallicum, Rorippa austriaca, Coronilla varia, Linum perenne, Rhus aromatica, Lamium amplexicaule, Myosotis sylvatica, Veronicastrum virginicum, Linaria dalmatica, Viburnum lantana, V. prunifolium, Symphoricarpos albus, Valeriana officinalis,* and a number of Compositae. Sixty grasses are merely listed. As can be seen, the revision is thorough, but the original text is retained wherever appropriate. The old illustrations are now scattered through the text and not as well reproduced. New illustrations have been added where needed and there is a list of selected references. More detailed information is often provided on county limits for species not occurring throughout Wisconsin, and maps help to orient the reader to the state. The keys are reset in a less readable format (uniform right margin for names and characters). Some problems in the previous keys remain: the key to families requires that one declare such essentially leafless plants as *Arceuthobium* to have "Leaves with branching veins or with all but the midvein inconspicuous"; it is very difficult for a student to distinguish *Orobanche* from *Corallorhiza* when the sole character in the key involves leaf venation! In the key to genera of Orchidaceae, the statement "each flower exceeded by its bract, which is about 1 cm wide" applies to only one of the two species in *Orchis.* And although *Valeriana* is said to be dioecious, this is not true of *V. uliginosa (V. sitchensis* var. *uliginosa).*

Changes do not always involve increase in species: *Amelanchier* has been converted to a "Jonesian" treatment, with loss of one species; and although the genus *Pyrus* has been split up, *Aronia* is reduced to a single species. Almost never are any synonyms (even from the previous edition) cited. Family names universally end in -aceae, as permitted (but not, as stated, preferred) by the Code. The so-called "perfect" binding keeps the small pages from lying flat and may prove less durable than the sewing of early printings of the 3rd edition. But overall we have a workable flora, generous in its comprehensive coverage of species, taxonomically and nomenclaturally congenial (to this reviewer, at least), reasonably priced, and most emphatically recommended to every reader of these pages.

–E. G. Voss

LEGUMINOSAE OF THE UNITED STATES: II. SUBFAMILY CAESALPINOIDAE. By Duane Isely. Memoirs of the New York Botanical Garden Vol. 25, No. 2. 1975. 228 pp.

This second part of Vol. 25 follows the pattern of the first (Mimosoideae), reviewed in this journal earlier (13: 166, 1974, with inexplicable errors in citing volume number, spelling the author's name, and alleging non-citation of maps). As before, the keys look good, there is considerable stress on cultivated species as well as native ones, and the commentary is refreshingly frank. Some overlapping and ambiguity is admitted in the keys based on vegetative characters, with the pointed observation that "it is better to be uncertain of determination than certain and wrong." The section on "Terminology" is essential reading, to learn about such things as the distinction between "ruderal" and "disturbed" and the use of "leafstalk" to include both petiole and rachis in a compound leaf. There are 84 distribution maps (some showing ranges of more than one taxon, none showing county boundaries in the Great Lakes region), but no citations of representative specimens and no illustrations.

—E. G. Voss

VEGETATION AND FLORA OF THE HURON MOUNTAINS. By James R. Wells & Paul W. Thompson. Occasional Papers of the Huron Mountain Wildlife Foundation No. 3. [1976]. 59 pp.

This is a thorough account of the vascular plants of one of Michigan's finest and wildest natural areas, about 90 square miles in rugged country northwest of Marquette, on Lake Superior. (While most of the area is in Marquette Co., a small portion is in Baraga Co., and therefore species in the checklist cannot be assumed to be reported from a specific county.) Over half the work consists of ecological background, including maps, descriptions of plant communities (with excellent photographs), and a list of big trees. The checklist is not annotated but includes common names—often manufactured—for almost every one of the nearly 800 species. (I have yet to meet anyone who distinguishes 66 species of *Carex* by common names!) The field work of Elzada U. Clover in the Huron Mountains is mentioned in the introduction but her collections, in the University of Michigan Biological Station herbarium, were evidently not examined. There is no indication as to which species are not considered indigenous.

Inconsistencies of style and countless typographical errors will irk the literate reader. This is the third number in its series, and none thus far has borne any date of publication. *Caragana,* a legume, is assigned to the Cruciferae. Work of J. S. Pringle cited as "unpublished" was in fact published in *The Michigan Botanist* in 1968—with acknowledgment to the Huron Mountain Wildlife Foundation. The phytogeographic notes in the section "Floristics" are rather random and omit some of the most interesting points. Why, for example, are *Cakile* and *Calamovilfa* known on Lake Superior only from the beach at the Huron Mountains? If the authors have truly found *Potamogeton lateralis* that species should no longer be considered extirpated in Michigan, where it has not otherwise been found since 1872 (in Van Buren Co.). If the Coastal Plain *Solidago tenuifolia* really grows in the Huron Mountains, that would be worth discussion!

One of the most interesting sections is the brief history of the Ives Lake area (by J. P. Case). The work is appropriately dedicated to the late William P. Harris, Jr., first president of the Huron Mountain Wildlife Foundation.

—E. G. Voss

SEDGES: CYPERUS TO SCLERIA. The Illustrated Flora of Illinois. By Robert H. Mohlenbrock. Southern Illinois University Press, Carbondale. 1976. 192 pp. $15.00.

This is the sixth volume in an ambitious series by its author-editor. One more volume (*Carex*) will complete the monocots, and if the price is the same as the latest, anyone with a large book budget will be able to own a complete flora of Illinois monocots for $75.00. The work is also useful in adjacent areas, of course, although it is surprising how many species of southern Michigan do not quite reach Illinois.

As in previous volumes, the keys are mostly good; there is an excellent glossary; references are cited; miscellaneous historical and identification notes are provided, in addition to brief descriptions and synonymy. Distribution maps show Illinois counties from which each taxon is known, and each is illustrated by useful drawings of details and a less useful habit sketch. The latter generally impress me not only as over-reduced and darkly inked but also unnaturally sinuous or drawn from wilted specimens. Anyone who knows the characteristic stiff leaves of *Dulichium arundinaceum* in the field, for instance, will hardly recognize fig. 54. The habit drawings of many species have had middle sections excised to make them fit on the page, sometimes leaving disembodied fragments (cf. fig. 84); at times the drawings of details are unnecessary and hence misleading (fig. 87 implies that the named form differs from the typical form in achene and scale characters), and other times they lack important features: the characteristic antrorse hairs at the base of the bristles in *Rhynchospora alba* are neither drawn nor mentioned in the text, which stresses achenes "emarginate" (but not in the sense in which that word is defined in the glossary).

The summary of taxa treated gives a total of 85 species in this volume—a far more realistic figure than the 2,699 species claimed on the dust jacket!

—E. G. Voss

PUBLICATIONS OF INTEREST

VASCULAR PLANTS OF THE NEVADA TEST SITE AND CENTRAL-SOUTHERN NEVADA: Ecologic and Geographic Distributions. By Janice C. Beatley. Technical Information Center, Office of Technical Information, Energy Research and Development Administration, [Washington, D. C.]. 1976. 306 pp. $9.75 (hard-cover, TID-26881 from NTIS, U. S. Department of Commerce, Springfield, Virginia 22161). This is an unexpectedly attractive book from a government agency. A third of it is devoted to a well illustrated consideration, with maps, of the desert environment and vegetation. The remainder is an annotated list (no keys) of over 1000 taxa found in a diverse area that straddles the boundaries of two large deserts and includes about 25 mountains or mountain ranges. Collections were made from 1957 through 1975 as part of the ecological studies undertaken to assess the effects of AEC activities on the native flora and fauna.

INSECT POLLINATION OF CULTIVATED CROP PLANTS. By S. E. McGregor. Agricultural Research Service, U. S. Department of Agriculture, Agriculture Handbook 496. 1976. 411 pp. $5.90 (GPO Stock No. 001-000-03549-5). A real bargain, this large volume (pages nearly 9 × 12 inches) begins with general material on pollination, pollination agents, and specifically on beekeeping in relation to pollination. The bulk of the text consists of discussions, with illustrations and many bibliographic references, of individual crops dependent upon or benefited by insect pollination. In alphabetical order by common names, these include about 150 different plants, tropical as well as temperate in origin. The work is thoroughly indexed, including an index of cited authors.

INDEX TO PLANT DISTRIBUTION MAPS IN NORTH AMERICAN PERIODICALS THROUGH 1972. Compiled by W. Louis Phillips & Ronald L. Stuckey. G. K. Hall & Co., Boston. 1976. xxxvii + 686 pp. $110.00. This enormous undertaking is a list of nearly 29,000 maps published in 268 periodicals which were systematically searched. Books (including numbers of some irregular serials—such as Bulletins of the Cranbrook Institute of Science) containing distribution maps are separately listed but not indexed. All groups—algae to flowering plants—are in a single alphabetical sequence using whatever name was published with each map. Geographical and geological journals, which might have been logical sources for maps, were not searched and Mexico was evidently not considered in North America. Otherwise, the coverage seems extremely thorough. For each map, its nature (outline, dot, county, etc.), scope, and author are indicated. This very useful guide to the literature will save hours of searching by taxonomists, plant geographers, environmental consultants, and others who need to know the distributions of plants.

EASTERN DECIDUOUS FOREST VOLUME 2 BEECH-MAPLE REGION. Inventory of Natural Areas and Sites Recommended as Potential Natural Landmarks. By Alton A. Lindsey & Linda K. Escobar. U.S. Department of the Interior, National Park Service, Natural History Theme Studies No. 3. 1976. 238 pp. Prepared for the National Registry of Natural Landmarks program, this inventory is preceded by a general discussion (34 pp.) of the beech-maple association and the maple-basswood association. Forested areas within these two forest regions as defined by E. Lucy Braun and already protected or "judged by qualified local observers to be worth considering for permanent protection" are then listed with brief descriptions. Twenty areas are listed for Michigan, compiled from a miscellany of published and unpublished sources. Four of the areas (Haven Hill, Woldumar, Newton Woods, and Shadbush Natural Area) are recommended (by whom is not stated) as potential Natural Landmarks. One of the best parts of this publication is the final paragraph of the authors' preface, which observes: "Any hope of a definitive inventory for a large area is futile. Of making many natural areas there is no end, provided that standards of quality are progressively relaxed. . . .It is the authors' hope for all regions that the period of emphasis on complete inventories on paper will soon be followed by one of greater activity in and better financing for actually acquiring and preserving the best areas that still lack the fullest possible protection."

ENDANGERED AND THREATENED VASCULAR PLANTS IN WISCONSIN. By Robert H. Read. Department of Natural Resources, Scientific Areas Preservation Council, Technical Bulletin 92. 1976. 60 pp. Includes general information on concepts of plant rarity and distribution patterns in Wisconsin, with an annotated list of 268 taxa (120 endangered, 106 threatened, 28 unknown but probably extirpated, and 14 extirpated). Many species and habitats are illustrated.

THE FACE OF RURAL AMERICA. The 1976 Yearbook of Agriculture. U.S. Department of Agriculture. 1976. 284 pp. $7.30. This year's volume introduces a new larger page size and is basically a picture-book, with short captions. Some of the photos are in color. Sections are titled Land, People, Machines, Weather, Special Events, Business of Agriculture, Livestock, Farm Life, and Harvest. Copies are available without charge from one's Congressmen.

WILD FLOWERS OF THE MIDWEST. By Katherine Mackenzie. Tundra Books of Northern New York, Plattsburgh. 1976. [96] pp. $2.95. Small, pastel water-color sketches and brief remarks in a pocket-size format. Michigan and Ohio are the easternmost of the states listed for the "Midwest," yet some of the species included barely reach this far west. Designed especially to appeal to children.

—E. G. Voss

MICHIGAN PLANTS IN PRINT
New Literature Relating to Michigan Botany

B. BOOKS, BULLETINS, SEPARATE PUBLICATIONS

Evans, Francis C. 1975. The Natural History of a Michigan Field. pp. 27-51 in Prairie: A Multiple View (ed. M. K. Wali). [Includes a list–with page evidently out of order–of higher plants from Evans Old Field, E. S. George Reserve, Livingston Co., with much other information on this well-studied site, and bibliography. See review in Mich. Bot. 15:214. Oct. 1976.]

Luer, Carlyle A. 1975. The Native Orchids of the United States and Canada Excluding Florida. N. Y. Bot. Gard. 361 pp. $40.00. [Many of the excellent color photographs (on 97 large plates) in this handsome new orchid book were taken in Michigan (counties cited), and there are Michigan observations throughout the text. Distribution maps include the state, but there are some problems; e.g., *Isotria medeoloides* although said to occur in Berrien Co. is mapped about 2 or 3 counties to the east; although the recent work of Stoutamire is approvingly cited, the map for *Platanthera grandiflora* shows it throughout Michigan and most of Wisconsin even though Stoutamire does not have it west of northeastern Ohio.]

McLinden, Fred. 1977. Field Book of Native Michigan Trees. McLinden Arboretum, Galesburg, Mich. 73 pp. $2.00 (plus $.75 postage & handling if ordered from the author). [Descriptive material and practical notes on identification, with ample space for annotations (no keys or illustrations for species); distributional information sometimes useful but often incomplete or misleading; size of "largest tree" gives only height, whereas "champions" in fact are based on a formula considering circumference as well.]

Schoenike, Roland E. 1976. Geographical Variations in Jack Pine (Pinus banksiana). Minnesota Agr. Exp. Sta. Tech. Bull. 304 (Forestry Ser. 21). 47 pp. [Numerous distribution maps include nature of variation at 6 Michigan sampling areas for a diversity of characters.]

Thompson, Paul W. 1975. The Floristic Composition of Prairie Stands in Southern Michigan. pp. 317-331 in Prairie: A Multiple View (ed. M. K. Wali). [Includes comparative list of species for stands in Newaygo, Berrien, St. Joseph, Jackson, Washtenaw, and Monroe cos., Mich., and Windsor, Ontario, with brief description of each stand. See review in Mich. Bot. 15:214. Oct. 1976.]

Tubbs, Carl H. 1976. Effect of Sugar Maple Root Exudate on Seedlings of Northern Conifer Species. U.S. Dep. Agr., For. Serv. Res. Note. NC-213. 2 pp. [Root exudate from Upper Peninsula seedling sugar maples inhibited growth of conifer seedlings; allelopathic effects also demonstrated on yellow birch.]

C. JOURNAL ARTICLES

Ammirati, Joseph F., & Martina S. Gilliam. 1975. Cortinarius, Section Dermocybe: Further studies on Cortinarius aureifolius. Beih. Nova Hedwigia 51:39-52. [Var. *psammophilus* cited from two Michigan counties.]

Bigelow, Howard E. 1975. Studies in the Tricholomataceae: Hygrophoropsis, Cantharellula, Myxomphalia, Omphaliaster. Beih. Nova Hedwigia 51:61-77. [Four species in these small genera cited from Michigan without further locality data.]

Bigelow, Howard. 1976. Studies on some lignicolous Clitocybes. Mem. N. Y. Bot. Gard. 28:9-15. [Three species, including the type of one new one, are noted from Michigan.]

Brunett, Fel V., & James E. Fitting. 1976. Plant remains. Chapter 6 in Archaeological excavations at the Marquette Mission site, St. Ignace Michigan, in 1972. Mich. Archaeol. 22:235-237. [Both the senior author's name and the name *Thuja* are consistently misspelled in this report of four plant genera in the form of charcoal, bark, and seed (*Acer, Betula, Thuja, & Vitis*) which do "not suggest any major environmental changes over the past 300 years."]

Burdsall, H. H., Jr., & O. K. Miller, Jr. 1975. A reevaluation of Panellus and Dictyopanus (Agaricales). Beih. Nova Hedwigia 51:79-92. [*P. stipticus* cited from Michigan without further locality.]

Catling, Paul M. 1974. A butterfly-trapping orchid. Newsletter Mich. Entomol. Soc. 19(1):1+3. [Includes observations on Cypripedium reginae in Michigan.]

Chinnappa, C. C., & J. K. Morton. 1976. Studies on the Stellaria longipes Goldie complex variation in wild populations. Rhodora 78:488-502. [Maps showing distribution and association of various morphological characters include symbols in Upper Peninsula, but no specific localities are cited.]

Clémençon, Heinz. 1975. Ultrastructure of hymenial cells in two boletes. Beih. Nova Hedwigia 51:93-98. [Data on *Tylopilus felleus* and *Suillus americanus*, two "Michigan boletes," apparently from the area of the U. of M. Biological Station but not otherwise explicitly cited.]

Cooke, Wm. Bridge. 1976. On Cyphellopsis anomala (Persoon ex Fries) Donk. Mem. N. Y. Bot. Gard. 28:32-37. [Michigan included among localities cited for certain spore sizes.]

Crum, Howard, Elizabeth G. Fisher, & Harold C. Burtt. 1972. Splachnum ampullaceum in West Virginia. Castanea 37:253-257. [Includes observations on this dung-inhabiting moss in Michigan.]

Davis, Margaret Bryan. 1976. Erosion rates and land-use history in southern Michigan. Environ. Conserv. 3:139-148. [Study at Frains Lake near Ann Arbor, based on sediment cores, including pollen and diatoms.]

Davis, Margaret Bryan. 1976. Pleistocene biogeography of temperate deciduous forests. Geoscience & Man 13:13-26. [After a summary of modern thought on glacial/interglacial cycles, considers migration of dominant forest trees into glaciated territory, with maps indicating advancing frontiers at 100-year intervals for pine (jack and/or red), white pine, hemlock, beech, hickory, and chestnut. Michigan was not reached via the same route for all, but is at one border or another for all.]

Edwards, Joan. 1976. Learning to eat by following the mother in moose calves. Am. Midl. Nat. 96:229-232. [General observations on Isle Royale; only balsam fir and *Viburnum edule* mentioned by name among food plants.]

Fitting, James E. (ed.) 1974. Contributions to the archaeology of the St. Ignace area. Mich. Archaeol. 20:117-286. [This special issue includes articles on five Mackinac Co. sites with brief notes on plant remains–chiefly charred fragments of various trees and in one instance corn; these notes are said to be contributed by Fel Brunett, whose name–like those of the plants–is usually misspelled.]

Frohlich, Michael W. 1976. Appearance of vegetation in ultraviolet light: Absorbing flowers, reflecting backgrounds. Science 194:839-841. [Includes observations on some Michigan dune plants, with photos, including *Cirsium pitcheri,* which has dark rather than cream heads in UV.]

Gentry, Johnnie L., Jr., & Robert L. Carr. 1976. A revision of the genus Hackelia (Boraginaceae) in North America, North of Mexico. Mem. N. Y. Bot. Gard. 26(1):121-227. [*H. virginiana* and *H. deflexa* var. *americana* cited from some Michigan localities.]

Isely, Duane. 1975. Leguminosae of the United States: II. Subfamily Caesalpinoideae. Mem. N. Y. Bot. Gard. 25(2). 228 pp. [See review, p. 91. *Cassia hebecarpa* (*C. marilandica* auct.), *Cercis canadensis,* and *Gleditsia triacanthos* are mapped in southern Lower Peninsula; *Cassia marilandica, C. fasciculata,* and *Gymnocladus dioica* are mapped as not quite reaching Michigan, although the latter two have been collected in the state.]

Shugart, Gary W. 1976. Effects of ring-billed gull nesting on vegetation. Jack-Pine Warbler 54:50-53. [Effects of trampling and over-fertilization on woody plants on South Manitou Island.]

Smith, Alexander H. 1976. Notes on Michigan Lactarii. Mem. N. Y. Bot. Gard. 28:208-217. [Thorough descriptions of four species, none of them new.]

The January issue (Vol. 16, No. 1) was mailed January 26, 1977.

CONTENTS

Chromosome Studies of Some Mosses of the Douglas Lake Region. IV
Jerry A. Snider 51

Pollen Analysis of Peat from a Sinkhole in the Garden Peninsula, Delta County, Michigan
Ronald O. Kapp & Thomas P. Means 55

Scleria reticularis New to the Michigan Flora
Gary J. Pierce & Richard W. Pippen 63

Dimorphism in *Collybia racemosa*
Roy Watling & Bryce Kendrick 65

Notes on the Floral Biology of *Plantago* in Michigan
Michael R. Mesler 73

Extent of Vegetative Reproduction in Eleven Species of *Sphagnum* from Northern Michigan
David M. Lane 83

Reviews 90

Publications of Interest 92

Michigan Plants in Print 94

On the cover: Male plants of the thalloid liverwort, Conocephalum conicum, *with antheridial receptacles. Photo taken near Grand Ledge, Eaton County, Michigan, on May 31, 1971 by Norton G. Miller*

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Editorial Board

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Herbarium, The University of Michigan, Ann Arbor, Michigan 48109

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Membership in the Michigan Botanical Club is open to anyone interested in its aims: conservation of all native plants; education of the public to appreciate and preserve plant life; sponsorship of research and publication on the plant life of the State; sponsorship of legislation to promote the preservation of Michigan native flora and to establish suitable sanctuaries and natural areas; and cooperation in programs concerned with the wise use and conservation of all natural resources and scenic features.

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Red Cedar Chapter:
Martha Davidson, 2669 Blue Haven Ct., East Lansing, Michigan 48823

ENDANGERED, THREATENED, AND RARE VASCULAR PLANTS IN MICHIGAN[1]

W. H. Wagner and E. G. Voss
Department of Botany and Herbarium
University of Michigan, Ann Arbor, 48109

J. H. Beaman
Department of Botany and Plant Pathology
Michigan State University, East Lansing, 48824

E. A. Bourdo
School of Forestry and Wood Products
Michigan Technological University, Houghton, 49931

F. W. Case
7275 Thornapple Lane, Route 180, Saginaw, 48603

J. A. Churchill and P. W. Thompson
Cranbrook Institute of Science, Bloomfield Hills, 48013

This list was prepared by the Technical Advisory Committee for Plants (W. H. Wagner, chairman) for the Program on Endangered and Threatened Species sponsored by the Michigan Department of Natural Resources. It is based on field experience of members of the Committee, together with information on monocots in Voss (1972), other published and unpublished information to the extent considered reliable, and specimens in the herbaria of the University of Michigan and Michigan State University.

According to the Michigan Endangered Species Act of 1974 (Act No. 203), an endangered species is "a species of fish or wildlife, or plant life which is in danger of extinction throughout all or a significant part of its range. . . ." A threatened species is "a species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. . . ." The Act (Sec. 4) directed the Natural Resources Commission to list the species which are determined to be "endangered or threatened within the state." After the first lists were drawn up by technical advisory committees appointed by the Department of Natural Resources, the Department provided the following supplementary explanations (undated brochure titled "Michigan's Endangered and Threatened Species Program"):

> The state list of "endangered" species will be those species listed by the Secretary of Interior as endangered and resident in any part of their life cycle in Michigan. It will also include those indigenous species which the State of Michigan feels should be included on the national list of endangered species because they are on the

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[1] Publication of this report is authorized by the Michigan Department of Natural Resources. The assistance of Mr. Jack D. Bails and Dr. Ralph I. Blouch of the DNR is gratefully acknowledged. We thank the Michigan Botanical Club, Inc. for financial support which made possible early publication of the report.

> verge of extinction. The definition refers to worldwide status of a species. Also, it recognizes subspecies of fish or wildlife, or plant life, or lower taxa in a common spatial arrangement, that reproduce and represent a truly unique, identifiable form.

The definition of threatened species is similarly explained as follows:

> The state list of "threatened" species includes those species, and lower taxa as defined under endangered, that are threatened with extirpation in Michigan. For the purposes of state law, the Michigan range is considered significant except when the state portion of the range is considered to be peripheral. Peripheral species will not be listed as "threatened" unless their populations are also threatened in their primary range outside of Michigan. Species whose range is now reduced to a relatively few isolated populations that do not interbreed are included within this definition, as are species which were once extirpated, but are now in the process of becoming re-established through introductions.

The rare or scarce species (not protected under Michigan law) is described by the Department of Natural Resources as follows:

> A species or lower taxa [*sic*] that while not "endangered" or "threatened" is extremely uncommon in Michigan and deserves further study and monitoring. Peripheral species, not listed as "threatened" may be included in this category along with those species which were once "threatened" or "endangered" but now have increasing or protected, stable populations.

The Technical Advisory Committee for Plants also designated a group of species as probably extinct or extirpated in Michigan. These are species which are no longer known to occur in the state after repeated search of likely places. Obviously they do not have protection under Michigan law, but these species should be included as endangered or threatened in case they are found still extant.

It should be realized that the Committee was especially concerned with taxa "endangered or threatened within the state" and within the United States. Peripheral species, for instance, which come south to Lake Superior, with the bulk of their range in Canada, were more likely to be listed as threatened in this state than southern species which range northward in the United States barely into Michigan (such as *Eclipta alba* and *Boltonia asteroides*).

In reviewing candidates for the list, the Committee attempted to apply criteria as uniformly and consistently as possible for all vascular plants known to be native in the state. The basic "rule of thumb" was documented occurrence in five or fewer counties (or major island groups, such as Isle Royale, usually treated in distribution maps as separate units from the mainland portion of a county—see Voss, 1972). However, recent collection was a factor given weight, species not having been found in recent years receiving especially careful consideration. Likewise, special attention was given to plants occurring in particularly vulnerable habitats, such as sand dunes and prairies, even if such plants are known from more than five mapping units. Plants likely to be exploited because of their showy, educational, edible, medicinal, or otherwise appealing or useful characteristics were likewise prime candidates for inclusion, although many of these are already covered by Michigan's "Christmas Tree Law" (see below). On the other hand, particularly inconspicuous plants (such as certain grasses and sedges) may not be listed as truly threatened even if known from only a few places. Not included in the list are about 80-100 species of undetermined status; these are of doubtful status primarily for reasons of taxonomy or identification: the Committee was not certain enough of their distinctness and/or the accuracy of their attribution to Michigan, and further study is required.

The list, in accord with Sec. 6 of the Act, includes only native species, subspecies, and varieties. Plants at the latter two taxonomic levels were considered, however, only when they were of special interest, such as their being nearly or entirely restricted to Michigan or having the type locality in the state. Introduced plants, whether or not naturalized, are excluded, as are cultivated plants. Intricate apomictic complexes were avoided; thus only one very distinctive species each of *Antennaria, Crataegus,* and *Rubus* is on the list. Routine hybrids, especially those without ability to reproduce or spread, are excluded, as are all forms and other minor variants (with the exception of one *Sarracenia* form).

Species in the endangered category on this list already have formal protection under Michigan law, as of December 2, 1976. However, the list of threatened species is tentative[2] pending formal review by the Natural Resources Commission, the Legislative Service Bureau, the Attorney General, and the Joint Legislative Committee on Administrative Rules. Not all the data needed for this review are yet available, especially distributional information and documentation of the basis for considering the plants to be threatened. This information is at present being prepared. With publication of the entire list, however, the Committee hopes that stimulus will be provided for all interested persons to help provide information about these or other species that should be considered for the list.

The Technical Advisory Committee will have a continuing function in the development of information about rare and endangered species and will be constantly available for advising the Department of Natural Resources. The list may be revised by addition or removal of species as necessary. Therefore, Committee members will be pleased to hear from anyone concerning the endangered species problem in Michigan. Concern may also be directed to the Rare Plants Committee of the Michigan Botanical Club, the Endangered and Threatened Species Committee of the Michigan Natural Areas Council, or the Department of Natural Resources. Through publication of the list, we hope to encourage monitoring of the problem in Michigan. In commenting on particular species, one should of course take into account the criteria and definitions stated above. Furthermore, documentation, in the form of photographs or specimens which can be critically examined, is essential. It may be noted that a task of paramount importance facing everyone concerned about rare and endangered species in Michigan is the identification and protection of areas where these species occur.

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[2] Except for *Panax quinquefolius* (ginseng) which has already been approved for inclusion on the list of threatened species.

In addition to the Michigan law protecting endangered and threatened species, there is also state legislation known as the "Christmas Tree Law" (Act 182, Public Acts of 1962) which provides protection for certain plants, including all trees, shrubs, vines, orchids, trilliums, gentians, club-mosses, North American lotus, birdfoot violet, trailing arbutus, and pipsissewa. Likewise, federal legislation (Public Law 93-205, the Endangered Species Act of 1973) provides protection for species on the United States list,[3] even if their condition in Michigan might not have qualified them for "endangered" or "threatened" status under our local criteria.

The following list is organized into three parts: pteridophytes, monocotyledons, and dicotyledons. Within each of the three groups the taxa are listed alphabetically by family, genus, and species. The list includes 328 taxa, of which 16 are designated endangered, 197 threatened, 90 rare, and 25 probably extinct. Common names are provided when possible, but it should be noted that such names can refer to more than one species, and a particular species may have more than one common name. Especially problematical are genera in which several or all species have the same common name. Ordinarily, under such circumstances (e.g., *Carex*) no common name is indicated. An asterisk (*) preceding the scientific name indicates that more than one infraspecific taxon of the species occurs in Michigan, but only the taxon listed has status on the list.

PTERIDOPHYTES: Club-mosses, Horsetails, and Ferns

LYCOPODIACEAE (Club-moss Family)

Lycopodium appressum Lloyd & Underwood. Threatened.
L. complanatum L. (sens. str.). Trailing Christmas-green. Rare.
L. ×*habereri* House. Threatened.
L. selago L. Fir clubmoss. Rare.
L. sitchense Rupr. Sitkan clubmoss. Endangered.
L. sp. nov. J. G. Bruce. Endangered.

EQUISETACEAE (Horsetail Family)

Equisetum ×*litorale* Kühlewein. Rare.
E. telmateia Ehrh. Giant horsetail. Probably extinct.

OPHIOGLOSSACEAE (Adder's-tongue Family)

**Ophioglossum vulgatum* var. *pycnostichum* Fern. Southeastern adder's-tongue. Threatened.

POLYPODIACEAE (Fern Family)

Asplenium montanum Willd. Mountain spleenwort. Probably extinct.
A. ruta-muraria L. Wall-rue. Threatened.
A. viride Huds. Green spleenwort. Rare.
Camptosorus rhizophyllus (L.) Link. Walking fern. Rare.
Cryptogramma acrostichoides R. Br. American rock-brake. Threatened.

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[3] This list has not yet become official, and it now appears that only a few species will be formally approved for inclusion in the near future. Under contract from the Office of Endangered Species of the U.S. Fish and Wildlife Service, the Smithsonian Institution has prepared a list of "Recommended Endangered and Threatened Species of the United States," which soon will be published. Although we have not had opportunity to examine this list, we have attempted to indicate the Michigan species which are included.

C. stelleri (Gmel.) Prantl. Slender cliff-brake. Rare.
Cystopteris dickieana Sim. Rare.
C. laurentiana (Weatherby) Blasdell. Rare.
Dennstaedtia punctilobula (Michaux) Moore. Hay-scented fern. Probably extinct.
Dryopteris assimilis S. Walker. Shield fern. Rare.
D. celsa (Wm. Palmer) Small. Log-fern. Threatened.
D. filix-mas (L.) Schott. Male fern. Threatened.
Gymnocarpium ×heterosporum W. H. Wagner. Threatened.
Pellaea atropurpurea (L.) Link. Purple cliff-brake. Threatened.
Phyllitis scolopendrium var. *americana* Fern. Hart's-tongue fern. Endangered. On U.S. list as endangered.
Woodsia abbeae Butters. Endangered.
W. alpina (Bolton) S. F. Gray. Northern woodsia. Threatened.
W. obtusa (Spreng.) Torrey. Blunt-lobed woodsia. Threatened.
Woodwardia areolata (L.) Moore. Netted chain-fern. Probably extinct.

SCHIZAEACEAE (Curly-grass Family)

Lygodium palmatum (Bernh.) Sw. Climbing fern. Threatened.

MONOCOTYLEDONS

ALISMATACEAE (Water-plantain Family)

Echinodorus tenellus (Mart.) Buchenau. Dwarf burhead. Probably extinct.
Sagittaria montevidensis Cham. & Schlecht. Arrowhead. Threatened.

ARACEAE (Arum Family)

**Arisaema triphyllum* var. *stewardsonii* (Britton) Stevens. Threatened.

COMMELINACEAE (Spiderwort Family)

Commelina erecta L. Day-flower. Probably extinct.
Tradescantia bracteata Small. Spiderwort. Threatened.
T. virginiana L. Spiderwort. Rare.

CYPERACEAE (Sedge Family)

Carex albolutescens Schw. Rare.
C. arcta Boott. Rare.
C. atratiformis Britton. Threatened.
C. concinna R. Br. Rare.
C. crus-corvi Kunze. Threatened.
C. davisii Schw. & Torrey. Rare.
C. decomposita Muhl. Threatened.
C. festucacea Willd. Rare.
C. frankii Kunth. Rare.
C. gravida Bailey. Rare.
C. haydenii Dewey. Rare.
C. howei Mack. Rare.
C. hyalinolepis Steudel. Rare.
C. media R. Br. Threatened.
C. oligocarpa Willd. Rare.
C. pallescens L. Rare.
C. platyphylla Carey. Threatened.
C. praegracilis W. Boott. Threatened.
C. richardsonii R. Br. Rare.
C. rossii Boott. Threatened.
C. scirpoidea Michaux. Threatened.
C. seorsa Howe. Threatened.
C. squarrosa L. Rare.
C. straminea Willd. Rare.
C. subimpressa Clokey. Rare.
C. sychnocephala Carey. Threatened.
C. trichocarpa Schk. Rare.
C. typhina Michaux. Threatened.
Cyperus flavescens L. Rare.
Eleocharis atropurpurea (Retz.) J. & C. Presl. Threatened.
E. caribaea (Rottb.) S. F. Blake. Threatened.
E. compressa Sulliv. Threatened.
E. engelmannii Steudel. Rare.
E. melanocarpa Torrey. Threatened.
E. parvula (R. & S.) Link. Probably extinct.
E. radicans (Poiret) Kunth. Threatened.
E. tricostata Torrey. Probably extinct.
Fimbristylis puberula (Michaux) Vahl. Threatened.
Fuirena squarrosa Michaux. Umbrella-grass. Threatened.
Hemicarpha micrantha (Vahl) Pax. Threatened.
Psilocarya scirpoides Torrey. Bald-rush. Threatened.
Rhynchospora globularis (Chapman) Small. Probably extinct.
Scirpus hallii Gray. Endangered.
S. olneyi Gray. Threatened.
S. torreyi Olney. Rare.
Scleria pauciflora Willd. Threatened.
S. reticularis Michaux. Threatened.

GRAMINEAE (see POACEAE)

IRIDACEAE (Iris Family)

Iris lacustris Nutt. Dwarf lake iris. Threatened. On U.S. list as threatened.
Sisyrinchium atlanticum Bickn. Threatened.
S. farwellii Bickn. Probably extinct.
S. hastile Bickn. Probably extinct.
S. strictum Bickn. Rare.

JUNCACEAE (Rush Family)

Juncus biflorus Ell. Rare.
J. brachycarpus Engelm. Threatened.
J. militaris Bigelow. Threatened.
J. scirpoides Lam. Threatened.
J. stygius L. Threatened.
J. vaseyi Engelm. Threatened.
Luzula parviflora (Ehrh.) Desv. Threatened.

LEMNACEAE (Duckweed Family)

Lemna valdiviana Phil. Threatened.

LILIACEAE (Lily Family)

Allium schoenoprasum L. (native variety). Chives. Threatened.
Camassia scilloides (Raf.) Cory. Wild-hyacinth. Threatened.
Disporum hookeri (Torrey) Nicholson. Fairy bells. Threatened.
D. maculatum (Buckley) Britton. Nodding mandarin. Probably extinct.
**Polygonatum biflorum* var. *melleum* (Farwell) Ownbey. Solomon-seal. Endangered.
Smilax herbacea L. (sens. str.). Carrion-flower. Rare.
Tofieldia pusilla (Michaux) Pers. False asphodel. Threatened.
Trillium nivale Riddell. Snow trillium. Probably extinct.
T. recurvatum Beck. Threatened.
T. sessile L. Toadshade. Threatened.
T. undulatum Willd. Painted trillium. Threatened.
T. viride Beck. Threatened.

ORCHIDACEAE (Orchid Family)

Arethusa bulbosa L. Arethusa or dragon's mouth. Rare.
Calypso bulbosa (L.) Oakes. Calypso or fairy-slipper. Threatened.
Cypripedium arietinum R. Br. Ram's head lady-slipper. Rare. On U.S. list as threatened.
**C. calceolus* var. *parviflorum* (Salisb.) Fern. (sens. str.). Yellow lady-slipper. Rare.
C. candidum Willd. White lady-slipper. Threatened. On U.S. list as threatened.
Habenaria ciliaris (L.) R. Br. Orange fringed orchid. Threatened.
H. flava (L.) Sprengel. Tubercled orchid. Rare. On U.S. list as threatened.
H. leucophaea (Nutt.) Gray. Prairie fringed orchid. Threatened. On U.S. list as threatened.
H. unalascensis (Sprengel) S. Watson. Alaska orchid. Threatened.
Isotria medeoloides (Pursh) Raf. Smaller whorled pogonia. Endangered. On U.S. list as endangered.
Isotria verticillata (Willd.) Raf. Whorled pogonia. Rare.
Listera auriculata Wieg. Auricled twayblade. Rare. On U.S. list as threatened.
Orchis rotundifolia Pursh. Round-leaved orchid. Threatened.
Spiranthes casei Catling & Cruise. Rare.
S. lucida (H. H. Eaton) Ames. Shining ladies' tresses. Rare.
Tipularia discolor (Pursh) Nutt. Cranefly orchid. Threatened.
Triphora trianthophora (Sw.) Rydb. Nodding pogonia or three birds orchid. Threatened.

POACEAE (Grass Family)

Agropyron dasystachyum (Hooker) Scribner. Threatened.
A. spicatum (Pursh) Scribner & J. G. Smith. Probably extinct.

Aristida dichotoma Michaux. Threatened.
A. longispica Poiret. Threatened.
A. necopina Shinners. Threatened.
A. tuberculosa Nutt. Probably extinct.
Beckmannia syzigachne (Steudel) Fern. Slough grass. Threatened.
Bouteloua curtipendula (Michaux) Torrey. Grama grass. Threatened.
Bromus pumpellianus Scribner. Threatened.
Calamagrostis lacustris (Kearney) Nash. Threatened.
C. stricta (Timm) Koeler. Threatened.
Danthonia intermedia Vasey. Rare.
Diarrhena americana Beauv. Threatened.
Digitaria filiformis (L.) Koeler. Probably extinct.
Elymus glaucus Buckley. Rare.
E. mollis Trin. Dune grass. Threatened.
Eragrostis capillaris (L.) Nees. Rare.
E. pilosa (L.) Beauv. Rare.
Festuca scabrella Torrey. Rough fescue. Threatened.
Glyceria acutiflora Torrey. Threatened.
Muhlenbergia cuspidata (Hooker) Rydb. Probably extinct.
M. richardsonis (Trin.) Rydb. Threatened.
Oryzopsis canadensis (Poiret) Torrey. Threatened.
Panicum leibergii (Vasey) Scribner. Threatened.
P. microcarpon Ell. Rare.
P. philadelphicum Trin. Rare.
P. spretum Schultes. Threatened.
P. verrucosum Muhl. Threatened.
Phleum alpinum L. Mountain timothy. Threatened.
Poa alpina L. Threatened.
P. canbyi (Scribner) Piper. Threatened.
P. paludigena Fern. & Wieg. Rare. On U.S. list as threatened.
Spartina patens (Aiton) Muhl. Salt-meadow cordgrass. Probably extinct.
Sporobolus heterolepis (Gray) Gray. Threatened.
Stipa comata Trin. & Rupr. Threatened.
Triplasis purpurea (Walter) Chapman. Sand grass. Threatened.
Trisetum spicatum (L.) Richter. Threatened.
Uniola latifolia Michaux. Wild-oats. Threatened.
**Zizania aquatica* L. var. *aquatica*. Wild-rice. Threatened.
**Z. aquatica* var. *interior* Fassett. Wild-rice. Threatened.

POTAMOGETONACEAE (Pondweed Family)

Potamogeton capillaceus Poiret. Threatened.
P. confervoides Reichenb. Threatened.
P. hillii Morong. Threatened. On U.S. list as threatened.
P. lateralis Morong. Probably extinct.
P. pulcher Tuckerman. Threatened.
P. vaseyi Robbins. Threatened.

RUPPIACEAE (Ditch-grass Family)

Ruppia maritima L. Ditch-grass. Threatened.

DICOTYLEDONS

ACANTHACEAE (Acanthus Family)

Justicia americana (L.) Vahl. Threatened.
Ruellia humilis Nutt. Threatened.

APIACEAE (Parsley Family)

Berula pusilla (Nutt.) Fern. Threatened.
Eryngium yuccifolium Michaux. Rattlesnake-master or button-snake-root. Threatened.
Osmorhiza depauperata Phil. [*O. obtusa* (C. & R.) Fern.]. Sweet cicely. Rare.

ARALIACEAE (Ginseng Family)

Oplopanax horridus (Sm.) Miq. Devil's-club. Threatened.
Panax quinquefolius L. Ginseng. Threatened. On U.S. list as threatened.

ARISTOLOCHIACEAE (Birthwort Family)

Aristolochia serpentaria L. Virginia snakeroot. Threatened.

ASCLEPIADACEAE (Milkweed Family)

Asclepias amplexicaulis Sm. Rare.
A. hirtella (Pennell) Woodson. Threatened.
A. ovalifolia Dcne. Threatened.
A. sullivantii Engelm. Threatened.

ASTERACEAE (Composite Family)

Agoseris glauca (Pursh) Raf. Threatened.
Antennaria rosea Greene. Threatened.
Arnica cordifolia Hooker [*A. whitneyi* Fern.]. Heart-leaved arnica. Endangered.
Aster modestus Lindley. Threatened.
A. nemoralis Aiton. Bog-aster. Rare.
A. sericeus Vent. Threatened.
Boltonia asteroides (L.) L'Hér. Boltonia. Rare.
Cirsium hillii (Canby) Fern. Hill's thistle. Threatened.
C. pitcheri (Torrey) Torrey & Gray. Pitcher's thistle. Threatened. On U.S. list as threatened.
Coreopsis palmata Nutt. Threatened.
Eclipta alba (L.) Hassk. Yerba-de-tajo. Rare.
Erigeron hyssopifolius Michaux. Threatened.
Eupatorium sessilifolium L. Upland boneset. Threatened.
Helianthus hirsutus Raf. Rare.
H. microcephalus Torrey & Gray. Small wood-sunflower. Threatened.
Lactuca pulchella (Pursh) DC. Blue lettuce. Threatened.
Liatris punctata Hooker. Blazing-star. Threatened.
Polymnia uvedalia L. Leafcup. Threatened.
Rudbeckia sullivantii C. L. Boynton & Beadle. Coneflower. Threatened.
Senecio congestus (R. Br.) DC. Marsh-fleabane. Probably extinct.
S. indecorus Greene. Threatened.
Silphium integrifolium Michaux. Threatened.
S. laciniatum L. Rosinweed or compass-plant. Threatened.
S. perfoliatum L. Cup-plant. Threatened.
Solidago decumbens Greene. Threatened.
S. houghtonii Torrey & Gray. Houghton's goldenrod. Threatened. On U.S. list as threatened.
S. lepida DC. Threatened.
S. remota (Greene) Friesner [distinct from *S. tenuifolia* Pursh?]. Threatened.
Tanacetum huronense Nutt. Lake Huron tansy. Threatened.

BERBERIDACEAE (Barberry Family)

Jeffersonia diphylla (L.) Pers. Twinleaf. Rare.

BORAGINACEAE (Borage Family)

Mertensia virginica (L.) Pers. Bluebells. Threatened.

BRASSICACEAE (Mustard Family)

Armoracia aquatica (Eaton) Wiegand. Lake-cress. Threatened.
Braya humilis (C. A. Meyer) Robinson. Threatened.
Draba arabisans Michaux. Threatened.
D. incana L. Threatened.
Subularia aquatica L. Awlwort. Threatened.

CACTACEAE (Cactus Family)

Opuntia fragilis (Nutt.) Haw. Fragile prickly-pear. Endangered.

CALLITRICHACEAE (Water-starwort Family)

Callitriche hermaphroditica L. Rare.
C. heterophylla Pursh. Rare.

CAPRIFOLIACEAE (Honeysuckle Family)

Lonicera involucrata (Richardson) Banks. Threatened.
Viburnum edule (Michaux) Raf. Squashberry or Mooseberry. Threatened.

CARYOPHYLLACEAE (Pink Family)

Arenaria macrophylla Hooker. Sandwort. Threatened.
Sagina nodosa (L.) Fenzl. Pearlwort. Threatened.
Stellaria longipes Goldie. Rare.

CISTACEAE (Rockrose Family)

Lechea leggettii Britton & Hollick. Threatened.
L. minor L. Rare.

COMPOSITAE (see ASTERACEAE)

CONVOLVULACEAE (Convolvulus Family)

Cuscuta campestris Yunker. Dodder. Threatened.
C. glomerata Choisy. Dodder. Threatened.
C. indecora Choisy. Dodder. Threatened.
C. pentagona Engelm. Dodder. Threatened.
C. polygonorum Engelm. Dodder. Threatened.

CRUCIFERAE (see BRASSICACEAE)

DROSERACEAE (Sundew Family)

Drosera ×*anglica* Hudson. Sundew. Rare.

EMPETRACEAE (Crowberry Family)

Empetrum nigrum L. Black crowberry. Threatened.

ERICACEAE (Heath Family)

Chimaphila maculata (L.) Pursh. Pipsissewa or spotted wintergreen. Rare.
Pterospora andromedea Nutt. Pine-drops. Threatened.
Vaccinium uliginosum L. Alpine blueberry. Threatened.
V. vitis-idaea L. Mountain-cranberry. Probably extinct.

FABACEAE (Pulse Family)

Amorpha canescens Michaux. Leadplant. Rare.
Baptisia leucantha Torrey & Gray. White or prairie false indigo. Threatened.
B. leucophaea Nutt. Cream wild indigo. Endangered.
Gymnocladus dioica (L.) K. Koch. Kentucky coffee-tree. Threatened.
Petalostemon purpureum (Vent.) Rydb. Red prairie clover. Endangered.
Strophostyles helvola (L.) Ell. Wild bean. Rare.

FAGACEAE (Beech Family)

Castanea dentata (Marsh.) Borkh. American chestnut. Endangered (native occurrences).

FUMARIACEAE (Fumitory Family)

Adlumia fungosa (Aiton) Greene. Climbing fumitory. Rare.

GENTIANACEAE (Gentian Family)

Gentiana alba Muhl. [*G. flavida* Gray]. Yellowish gentian. Rare.
G. linearis Froel. Closed gentian. Threatened.
G. puberula Michaux. Threatened.
G. saponaria L. Soapwort gentian. Endangered.
Sabatia angularis (L.) Pursh. Rose-pink. Threatened.
Swertia caroliniensis (Walter) Kuntze. American columbo. Rare.

HALORAGACEAE (Water-milfoil Family)

Myriophyllum alterniflorum DC. Rare.

M. farwellii Morong. Threatened.

HIPPOCASTANACEAE (Buckeye Family)

Aesculus glabra Willd. Ohio buckeye. Threatened.

HYDROPHYLLACEAE (Waterleaf Family)

Phacelia franklinii (R. Br.) Gray. Threatened.

JUGLANDACEAE (Walnut Family)

Carya laciniosa (Michaux) Loud. Big shellbark hickory. Rare.

LABIATAE (see LAMIACEAE)

LAMIACEAE (Mint Family)

Pycnanthemum verticillatum (Michaux) Pers. Mountain-mint. Rare.
Scutellaria parvula var. *leonardii* (Epling) Fern. Skullcap. Rare.
Trichostoma brachiatum L. [*Isanthus brachiatus* (L.) BSP.] False pennyroyal. Threatened.
T. dichotomum L. Bastard pennyroyal. Threatened.

LEGUMINOSAE (see FABACEAE)

LENTIBULARIACEAE (Bladderwort Family)

Pinguicula vulgaris L. Butterwort. Threatened.

LYTHRACEAE (Loosestrife Family)

Rotala ramosior (L.) Koehne. Tooth-cup. Rare.

MALVACEAE (Mallow Family)

Hibiscus palustris L. Swamp rose-mallow. Threatened.

MELASTOMATACEAE (Melastoma Family)

Rhexia virginica L. Rare.

MORACEAE (Mulberry Family)

Morus rubra L. Red mulberry. Rare.

NYMPHAEACEAE (Water-lily Family)

Nelumbo pentapetala (Walter) Fern. [*N. lutea* (Willd.) Pers.]. American lotus. Endangered.
Nuphar microphylla (Pers.) Fern. Yellow pond-lily. Threatened.
Nymphaea tetragona Georgi. Water-lily. Threatened.

ONAGRACEAE (Evening-primrose Family)

Epilobium palustre L. Willow-herb. Rare.
Gaura longiflora Spach [*G. filiformis* Small]. Gaura. Threatened.
Ludwigia alternifolia L. Seedbox. Threatened.

OROBANCHACEAE (Broom-rape Family)

Orobanche fasciculata Nutt. Broom-rape. Threatened.

OXALIDACEAE (Wood-sorrel Family)

Oxalis violacea L. Violet wood-sorrel. Probably extinct.

PLANTAGINACEAE (Plantain Family)

Littorella americana Fern. Rare.
Plantago cordata Lam. Probably extinct.

POLEMONIACEAE (Phlox Family)

Phlox maculata L. Wild sweet William. Threatened.
Polemonium reptans L. Jacob's ladder. Threatened.

POLYGONACEAE (Buckwheat Family)

Polygonum careyi Olney. Threatened.
P. viviparum L. Alpine bistort. Threatened.
Rumex maritimus L. Golden dock. Rare.

RANUNCULACEAE (Crowfoot Family)

Clematis verticillaris DC. Purple clematis. Rare.
Hydrastis canadensis L. Golden-seal. Threatened. On U.S. list as threatened.
Ranunculus rhomboideus Goldie. Prairie buttercup. Threatened.

RHAMNACEAE (Buckthorn Family)

Ceanothus sanguineus Pursh. Wild-lilac. Threatened.

ROSACEAE (Rose Family)

Chamaerhodos nuttallii var. *keweenawensis* Fern. Endangered.
Crataegus douglasii Lindley. Hawthorn. Rare.
Dalibarda repens L. False violet. Threatened.
Filipendula rubra (Hill) Robinson. Queen-of-the-prairie. Threatened.
Geum triflorum Pursh. Avens. Threatened.
G. vernum (Raf.) Torrey & Gray. Avens. Rare.
Potentilla hippiana Lehm. Cinquefoil. Threatened.
P. pensylvanica L. Cinquefoil. Threatened.
Prunus alleghaniensis var. *davisii* Wight. Alleghany plum. Rare.
Rubus acaulis Michaux. Dwarf raspberry. Threatened.
Sanguisorba canadensis L. Canadian burnet. Threatened.

SALICACEAE (Willow Family)

Populus heterophylla L. Swamp or black cottonwood. Threatened.
Salix pellita Andersson. Rare.
S. pyrifolia Andersson. Balsam-willow. Rare.

SARRACENIACEAE (Pitcher-plant Family)

**Sarracenia purpurea* f. *heterophylla* (Eaton) Fern. Pitcher-plant. Threatened.

SAXIFRAGACEAE (Saxifrage Family)

Parnassia palustris var. *neogaea* Fern. Grass-of-Parnassus. Rare.
Ribes oxyacanthoides L. Gooseberry. Threatened.
R. setosum Lindley. Gooseberry. Rare.
Saxifraga aizoon Jacq. Yellow mountain saxifrage. Threatened.
S. tricuspidata Rottb. Saxifrage. Threatened.

SCROPHULARIACEAE (Figwort Family)

Aureolaria auriculata (Michaux) Farwell. Probably extinct.
Besseya bullii (Eaton) Rydb. Threatened.
Buchnera americana L. Blue-hearts. Probably extinct.
Castilleja septentrionalis Lindley. Indian paintbrush. Threatened.
Chelone obliqua L. Purple turtlehead. Endangered.
Collinsia parviflora Douglas ex Lindley. Threatened.
Euphrasia arctica Lange (sens. lat.). Eyebright. Threatened.
Gerardia gattingeri Small. Gerardia. Threatened.
Gratiola lutea Raf. [*G. aurea* Muhl.] Hedge-hyssop. Threatened.
Lindernia anagallidea (Michaux) Pennell. False pimpernel. Threatened.
Mimulus alatus Aiton. Monkey-flower. Threatened.
**M. glabratus* var. *michiganensis* (Pennell) Fassett. Monkey-flower. Threatened. On U.S. list as threatened.

ULMACEAE (Elm Family)

Celtis tenuifolia Nutt. Dwarf hackberry. Rare.

UMBELLIFERAE (see APIACEAE)

VALERIANACEAE (Valerian Family)

Valeriana ciliata Torrey & Gray. Valerian. Rare.
Valerianella chenopodifolia (Pursh) DC. Threatened.

VERBENACEAE (Vervain Family)

Verbena simplex Lehm. Vervain. Rare.

VIOLACEAE (Violet Family)
- *Hybanthus concolor* (T. F. Forster) Sprengel. Green violet. Rare.
- *Viola labradorica* Schrank. Rare.
- *V. novae-angliae* House. Threatened.
- *V. palmata* L. Rare.
- *V. pedatifida* G. Don. Threatened.

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COMMENTARY ON ENDANGERED AND THREATENED PLANTS IN MICHIGAN[1]

John H. Beaman
Department of Botany and Plant Pathology
Michigan State University, East Lansing, 48824

Well-articulated concern for the protection of rare plants in Michigan extends at least as far back in time as Beal's *Michigan Flora* (1905). Only recently, however, has there been organized effort to review the status of rare and endangered plants in the state. Much of the current interest has been generated through the increasingly obvious and alarming effects of man's activities on environmental quality. Public concern has led to both federal and state legislation on rare and endangered species. The Endangered Species Act of 1973 (Public Law 93-205) required the preparation of a list of endangered and threatened plants in the United States. It also encouraged the development of state programs for the conservation of endangered and threatened species. In response the Michigan legislature moved quickly to enact complementary legislation by passing its own Endangered Species Act of 1974 (Act No. 203, Public Acts of 1974). According to this Act, the Department of Natural Resources was given responsibility for conducting "investigations on fish, plants, and wildlife in order to develop information relating to population, distribution, habitat needs, limiting factors, and other biological and ecological data to determine management measures necessary for their continued ability to sustain themselves successfully." The Natural Resources Commission was charged with promulgating "a rule listing those species of fish, plants, and wildlife which are determined to be endangered or threatened within the state."

To help accomplish these objectives the Department of Natural Resources appointed several technical advisory committees to prepare lists of the various groups of endangered and threatened animals and plants. The list of plants published in the article (Wagner et al., 1977) accompanying this paper is the first result of the deliberations of the Technical Advisory Committee for Plants.[2] My commentary is made possible by this list.

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[1] Presented at the Symposium on Rare and Endangered Species in Michigan, Zoology Section, Michigan Academy of Science, Arts and Letters, March 19, 1976, Philip T. Clampitt, Organizer. Financial support from the Michigan Natural Areas Council, Inc. made possible early publication of this paper.

In comparison with certain other states, the problem of rare and endangered plants in Michigan may not appear to be serious. For example, on the current United States list [*Federal Register* 41(117), June 16, 1976], 286 endangered species are reported for California, 110 for Texas, 83 for Florida, and 63 for Arizona. Nearly 50 percent of the native flora of Hawaii is regarded as endangered, threatened, or extinct. In contrast, only two endangered species on the U.S. list occur in Michigan. Nevertheless, there are many rare plants in Michigan, many which have become less common in recent years, and even 25 species which are probably extinct.

Although rare and endangered plants in Michigan may not appear numerous in comparison with the states noted above, the number of plants on the Michigan list is high compared with animals listed for the state. A summary comparison of endangered, threatened, and rare plants and animals in Michigan is provided in Table 1.

REASONS FOR RARE AND ENDANGERED PLANTS IN MICHIGAN

Most of the plants included on the list have always been relatively uncommon. In many cases these plants are rare in Michigan because they are at the edge of their range or are disjunct from other areas where they are more abundant. Michigan is somewhat central geographically to eastern North America, and many rather widely distributed species barely extend into the state from various directions. Crow's (1969) phytogeographical analysis of a

TABLE 1. Endangered, threatened, and rare species in Michigan.*

	Endangered	Threatened	Rare	Total
Mollusks	2	19	9	30
Insects	3	0	5	8
Fishes	6	9	0	15
Amphibians	0	3	1	4
Reptiles	0	4	4	8
Birds	2	10	8	20
Mammals	2	4	7	13
All animals	15	49	34	98
Plants	16	197	90	303
Total	31	246	124	401

*Data for animals based on undated brochure by Michigan Department of Natural Resources titled "Michigan's Endangered and Threatened Species Program."

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[2] Membership of the Committee is: W. H. Wagner, Jr., chairman, J. H. Beaman, E. A. Bourdo, F. W. Case II, J. A. Churchill, P. W. Thompson, and E. G. Voss.

southern Michigan bog indicates that its plants appear to have been derived from four important sources: 36 percent have southern affinities, 42 percent have eastern affinities, 10 percent represent a cordilleran extension, and two percent are of Alaskan affinity (cf. also Voss, 1972, pp. 21-23). The composition of other community types would differ in percentages of species derived from various regions, but the areas contributing both rare and common species to our flora are generally the same. In addition to distribution patterns which relate to the rarity of various species, habitat requirements are another important factor. Michigan presents a diversity of habitats including streams, lakes, bogs and other wetlands, prairies, woods, rock outcrops, and dunes which are the essential habitats for certain species. In most cases the rare plants have limited tolerance ranges and tend to be restricted to one kind of habitat.

Although limited distribution and tolerance range are major bases for rarity, other factors contribute to the problem. These include diseases such as the chestnut blight, which has virtually exterminated the American chestnut throughout its range in North America. No elms are on the list, but it appears that because of the Dutch elm disease their fate may soon parallel that of the chestnut. Increasing rarity of some species has resulted from commercial exploitation. Ginseng has been nearly extirpated throughout much of its range because of intensive collecting for medicinal purposes and golden-seal is now being heavily collected for the same reason. Other types of exploitation include the use of wild plants in floral decorations, as for example clubmosses that have been collected by the truckload in the Upper Peninsula.

The principal reason for increasing rarity of many species in Michigan, however, is industrial development, urban and suburban sprawl, highway construction, agriculture, and even recreation and tourism. For example, many of the endangered and threatened species in Michigan occur in the southeastern corner of the state where some type of development is touching almost every square inch of land except in preserved natural areas. Industrial wastes in streams and lakes have reduced various aquatic plant populations, as has channelizing and damming of streams. Sand mining and off-road vehicle activities threaten species restricted to dunes. The current fad for edible wild plants could also have an adverse effect on populations of rare plants. Even the realization by some people that a plant is rare may subject it to exploitation as a trophy.

OVERALL DISTRIBUTION PATTERNS OF ENDANGERED AND THREATENED SPECIES

Few taxa of vascular plants are entirely restricted to Michigan, and there is generally something taxonomically questionable about those that are considered to be endemic. Nevertheless, the Great Lakes region does have several distinctive endemic plants, including *Iris lacustris* (dwarf lake iris), *Cirsium pitcheri* (Pitcher's thistle), *Solidago houghtonii* (Houghton's goldenrod), and *Tanacetum huronense* var. *huronense* (Lake Huron tansy). These shoreline plants, centered around the straits of Mackinac, have been mapped and discussed by Guire and Voss (1963). All four taxa are included on the list as threatened.

A major floristic element involving endangered and threatened species comes into Michigan from the north. These species are found principally in the Upper Peninsula, particularly on Isle Royale and the Keweenaw Peninsula. A good example of this distribution pattern is *Empetrum nigrum* (black crowberry), a circumpolar species which in Michigan occurs only in the Upper Peninsula. Its distribution in the Lake Superior region has been mapped by Soper and Voss (1964).

One of the most remarkable floristic elements in Michigan is the Atlantic Coastal Plain disjuncts. These plants were discussed many years ago in a pioneering phytogeographic study by Peattie (1922), but they still deserve more detailed investigation. For example, Fernald (1942) sharply criticized the practice of some authors (including apparently Hanes, 1942) "to assume that almost any plant occurring east of Lake Michigan, and especially from east of the Alleghenies or the uplands of central-western New York and Pennsylvania, is a Coastal Plain species." An enumeration of Coastal Plain disjuncts (in a broader sense than Fernald might have accepted) listed as endangered, threatened, and probably extinct is provided in Table 2. This list includes more than one-third of all plants in Michigan that might be interpreted as of

TABLE 2. Status in Michigan of 23 endangered, threatened, and probably extinct Coastal Plain disjuncts.*

Species	Status
Aristida tuberculosa	Probably extinct
Carex seorsa	Threatened
Echinodorus tenellus	Probably extinct
Eleocharis caribaea	Threatened
E. melanocarpa	Threatened
E. radicans	Threatened
E. tricostata	Probably extinct
Fuirena squarrosa	Threatened
Isotria medeoloides	Endangered
Juncus militaris	Threatened
J. scirpoides	Threatened
Nelumbo pentapetala	Endangered
Panicum spretum	Threatened
P. verrucosum	Threatened
Potamogeton capillaceus	Threatened
P. lateralis	Probably extinct
Psilocarya scirpoides	Threatened
Rhynchospora globularis	Probably extinct
Scirpus hallii	Endangered
Scleria reticularis	Threatened
Sisyrinchium altanticum	Threatened
Solidago remota (if included in *S. tenuifolia*)	Threatened
Spartina patens	Probably extinct

*Designation as Coastal Plain disjunct based on data from Fernald (1950), Peattie (1922), and Voss (1972).

Coastal Plain affinity. A narrower interpretation of Coastal Plain disjuncts would likely increase the percentage of these species on the endangered and threatened list.

Numerous non-disjunct species also have ranges that are basically eastern North American. An example is the threatened *Gentiana linearis* (linear leaved gentian), mapped by Pringle (1968) and noted by him to be restricted to acid soils derived from granitic rocks.

Many species extend into the state from the south, and among those on the threatened list is *Ophioglossum vulgatum* var. *pycnostichum* (southeastern adder's tongue). The range of this taxon, known in Michigan only from Lenawee county, has been mapped by Wagner (1971). A similar pattern is seen in *Helianthus microcephalus* (small wood-sunflower) mapped by Heiser et al. (1969, p. 170). Species extending into the state from the southwest and west are frequently prairie plants. The floristic composition of prairie stands in southern Michigan has been discussed by Thompson (1975), who notes that 409 species occur in the prairies included in his study. It can be seen from Table 4 that with reference to habitat, prairie plants constitute the second largest group of endangered and threatened species in Michigan.

Paralleling the Coastal Plain disjuncts but coming from the opposite direction and with a concentration in northern Michigan is the cordilleran element. A good example is *Oplopanax horridus* (devil's club), which in eastern North America occurs only on Isle Royale and adjacent small islands in Lake Superior and in the Thunder Bay District, Ontario, but in the west extends from Oregon and Montana to Alaska (mapped by Fernald, 1925). *Disporum hookeri* var. *oreganum* (fairy bells) is a western taxon recently discovered in the Porcupine Mountains by Paul Thompson (Voss, 1972). Other representatives of the disjunct western element included on the endangered and threatened list are *Arnica cordifolia* (heart-leaved arnica), *Bromus pumpellianus* (brome grass), *Ceanothus sanguineus* (wild-lilac), *Festuca scabrella* (rough fescue), and *Habenaria unalascensis* (Alaska orchid).

AREAS OF CONCENTRATION OF ENDANGERED AND THREATENED SPECIES

To determine the areas in Michigan where endangered and threatened species are concentrated, I have analyzed by county the distribution records for all species on the list (distribution data for dicots are preliminary). From Table 3 it can be seen that the largest number of these plants is known from Kalamazoo County. Although this figure results in part from the extremely thorough collecting by the late Mr. and Mrs. Clarence Hanes for their flora of Kalamazoo County, the record is not entirely artifact. Other counties in southwestern Michigan not so well collected also have large numbers of endangered and threatened species.

As a graphic means for visualizing the areas in Michigan where endangered and threatened plants are concentrated, the counties with high numbers are shown in Figure 1 and those with low numbers in Figure 2. The two maps have a close inverse relationship. Collecting activities may have contributed somewhat to these patterns, but there is indeed a concentration

TABLE 3. Michigan counties with large numbers of threatened, endangered, and probably extinct plants.

	Threatened	Endangered	Probably extinct	Total
Kalamazoo	48	1	1	50
Isle Royale (Keweenaw)	40	–	1	41
Keweenaw (mainland)	30	2	5	37
Berrien	28	2	1	30
Washtenaw	24	1	1	26
Cass	22	–	2	24
Kent	23	–	1	24
Van Buren	18	2	3	23
St. Clair	19	1	2	22
Monroe	18	2	1	21
Wayne	19	–	2	21
Emmet	16	–	1	17
St. Joseph	15	–	2	17
Cheboygan	16	–	–	16

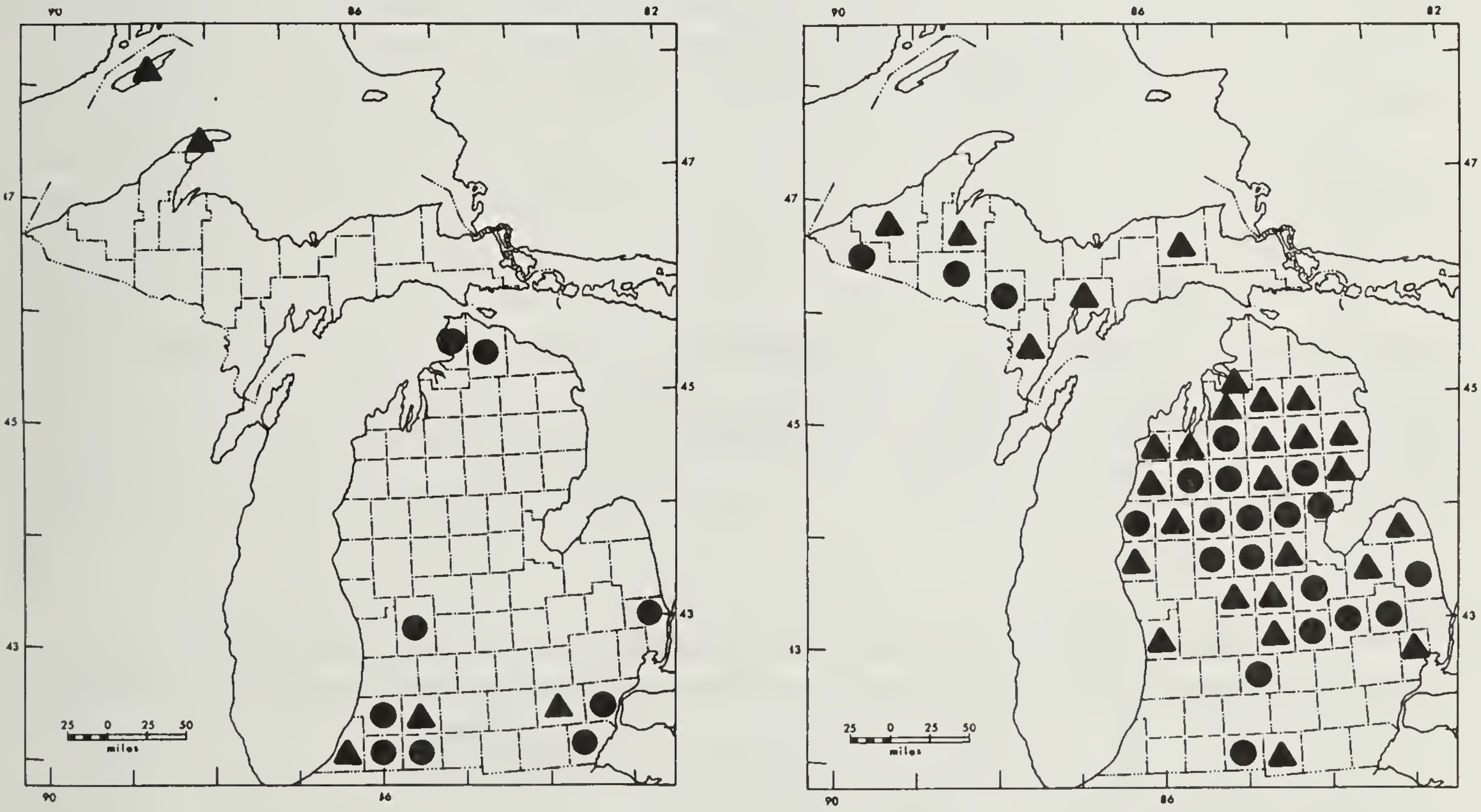


Fig. 1 (left). Michigan counties with large numbers of endangered or threatened species. Counties indicated with a triangle have from 24 to 49 endangered or threatened species; those with a solid circle have from 15 to 22. Fig. 2 (right). Michigan counties with few threatened species. Counties indicated with a triangle have three to five threatened species; those with a solid circle have from none to two.

of rare species in the southeastern and southwestern corners of the state, at the northern tip of the Lower Peninsula, and in Keweenaw County and on Isle Royale. Conversely, the smallest number of these species is found in the central areas of the state, particularly away from the lake shorelines.

HABITATS AND DISTRIBUTION OF ENDANGERED AND THREATENED SPECIES

Although it is often difficult to precisely categorize or define the habitat of a species, this is generally easier for rare species than for those of greater abundance. I have therefore attempted to analyze occurrence by habitat of the endangered and threatened plants, recognizing five major habitat categories. The results are shown in Table 4. Some species for which good habitat data are lacking or which occur in more than one type of habitat are left in an unclassified category. Under the category of threatened species, the habitats of pteridophytes, monocots, and dicots have been separately analyzed because of differences in quality of the data, that for monocots and pteridophytes being much better than that for the dicots which are still quite incompletely studied. In spite of the differences in data quality, there are strong parallels in the three groups.

An especially large number of endangered and threatened plants occur in aquatic and wetlands habitats. This is to be expected in the monocots, which in total include a high percentage of aquatic species. Likewise, a rather high number of dicots occur in prairie habitats. The predominance of pteridophytes is found on rock outcrops. A listing of the endangered species in Michigan according to habitat is provided in Table 5.

It has been noted above that endangered and threatened species are concentrated in certain areas of the state. These plants occur principally in the five major habitat types designated in Table 4. When distributional and habitat data are examined together it can be seen that characteristic patterns emerge for many of the species. Using as examples 48 threatened species of monocots with the maps from Voss's (1972) *Michigan Flora,* these patterns are illustrated in Figures 3-6. Among the numerous aquatic and wetlands plants it may be noted that some species are concentrated in the southeastern corner

TABLE 4. Habitats of probably extinct, endangered, and threatened plants in Michigan.

	Probably extinct	En-dangered	Threatened				Total
			Pterido-phytes	Monocots	Dicots	All threatened	
Aquatic and wetlands	9	3	1	45	33	79	91
Prairies, open areas, fields	9	3	–	6	24	30	42
Rock outcrops, bluffs	3	6	6	8	13	27	36
Woodlands	2	4	2	10	13	25	31
Dunes and other sandy areas	–	–	–	11	3	14	14
Unclassified	2	–	3	5	14	22	24
Total	25	16	12	85	100	197	238

TABLE 5. Classification by habitat of 16 endangered plants in Michigan.

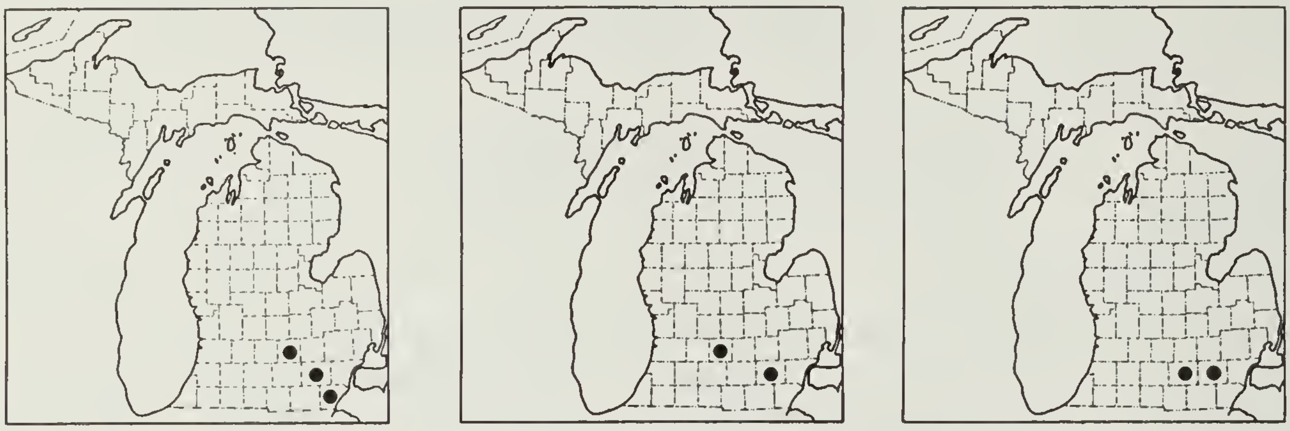
- Aquatic and wetlands
  - *Chelone obliqua,* purple turtlehead
  - *Nelumbo pentapetala,* American lotus
  - *Scirpus hallii*
- Rock Outcrops
  - *Lycopodium* sp. nov. (in wet borrow pits)
  - *L. sitchense,* Sitka club-moss (in borrow pits)
  - **Phyllitis scolopendrium* var. *americana,* hart's-tongue fern
  - *Woodsia abbeae*
  - *Chamaerhodos nuttallii* var. *keweenawensis*
  - *Opuntia fragilis,* fragile prickly-pear
- Prairies
  - *Baptisia leucophaea,* cream wild indigo
  - *Gentiana saponaria,* soapwort gentian
  - *Petalostemon purpureum,* red prairie clover
- Woodlands
  - *Arnica cordifolia,* heart-leaved arnica
  - *Castanea dentata,* American chestnut
  - **Isotria medeoloides,* smaller whorled pogonia
  - *Polygonatum biflorum* var. *melleum,* Solomon-seal

*On U.S. Endangered List.

of the state, others in the southwest, and still others have a more generally southern distribution, while a fourth group is northern. All six species used as examples of the southwestern pattern are Coastal Plain disjuncts. The species occurring in prairies and fields illustrate a generally southern distribution, which of course corresponds to the occurrence of prairie habitats in Michigan. Those on rock outcrops are northern, where the principal rock outcrops occur. Woodland species show the least characteristic patterns, which is to be expected because this habitat is well represented throughout the state (although there is a predominance of woodland species to the south). Species of dunes and other sandy areas might be expected to occur along shores of the Great Lakes, which is frequently the case. A notable exception is *Festuca scabrella* (rough fescue), a northwestern disjunct found on the sands of the jack pine plains in the north-central Lower Peninsula.

CONCLUSIONS

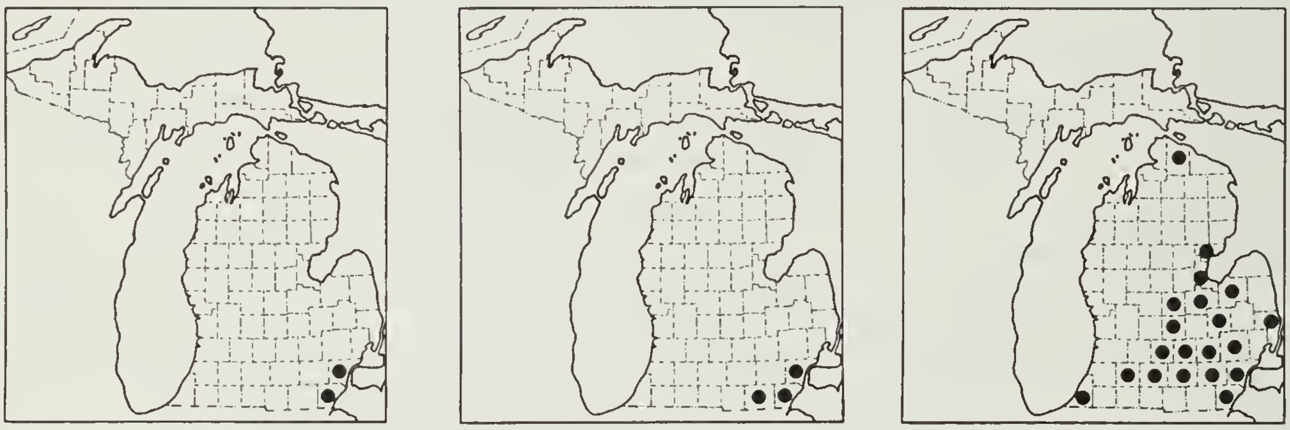
New laws at the federal and state levels have resulted in national and state lists of endangered and threatened species. However, the work in protecting these species has just begun. The Michigan list of threatened plants requires extensive documentation before it can be made official. The listing of plants in all categories (i.e., endangered, threatened, rare, probably extinct) represents a first attempt rather than a final document. At present about 100 species have been left in a questionable limbo (i.e., not listed) because of taxonomic or other problems. Monitoring of the species listed to determine



321. Carex decomposita

494. Eleocharis radicans

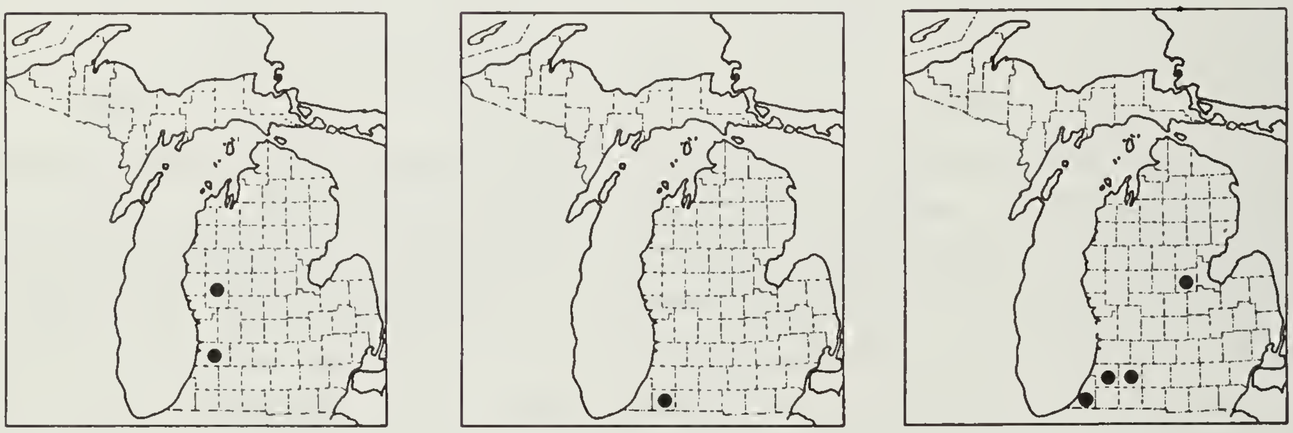
502. Eleocharis caribaea



590. Juncus brachycarpus

655. Camassia scilloides

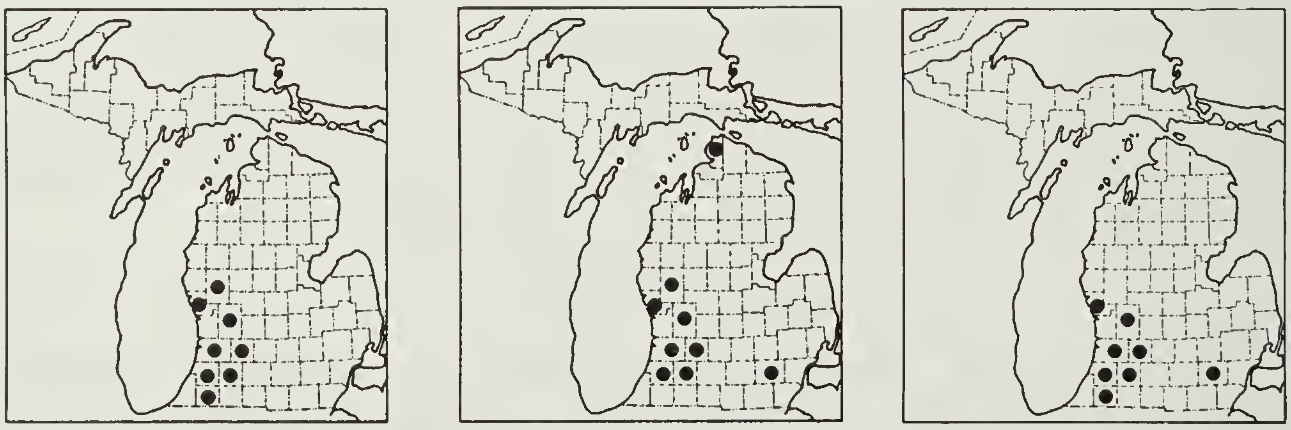
689. Habenaria leucophaea



41. Potamogeton capillaceus

268. Panicum verrucosum

335. Carex seorsa

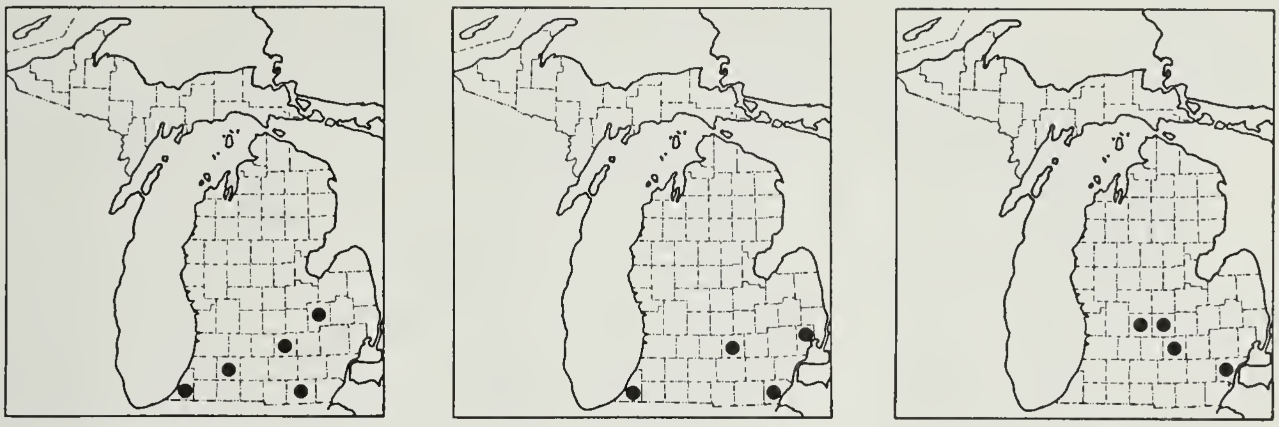


497. Eleocharis melanocarpa

516. Psilocarya scirpoides

537. Fuirena squarrosa

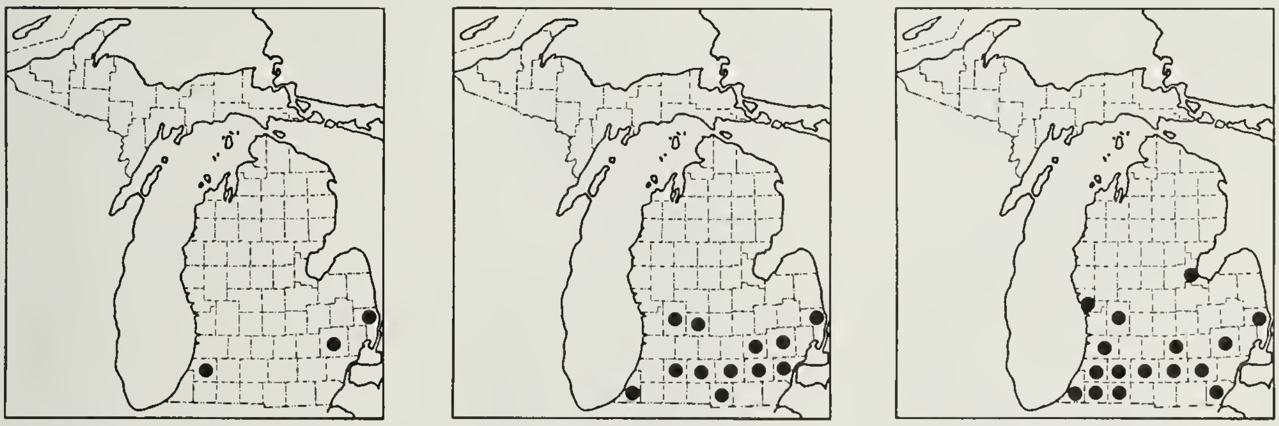
Fig. 3. Top two rows: Selected threatened monocots of aquatic and wetland habitats occurring in southeastern Michigan. Bottom two rows: Selected threatened monocots of aquatic and wetland habitats occurring in southwestern Michigan (all Coastal Plain disjuncts). Maps from Voss (1972), used with permission of Cranbrook Institute of Science.



107. Diarrhena americana

324. Carex crus-corvi

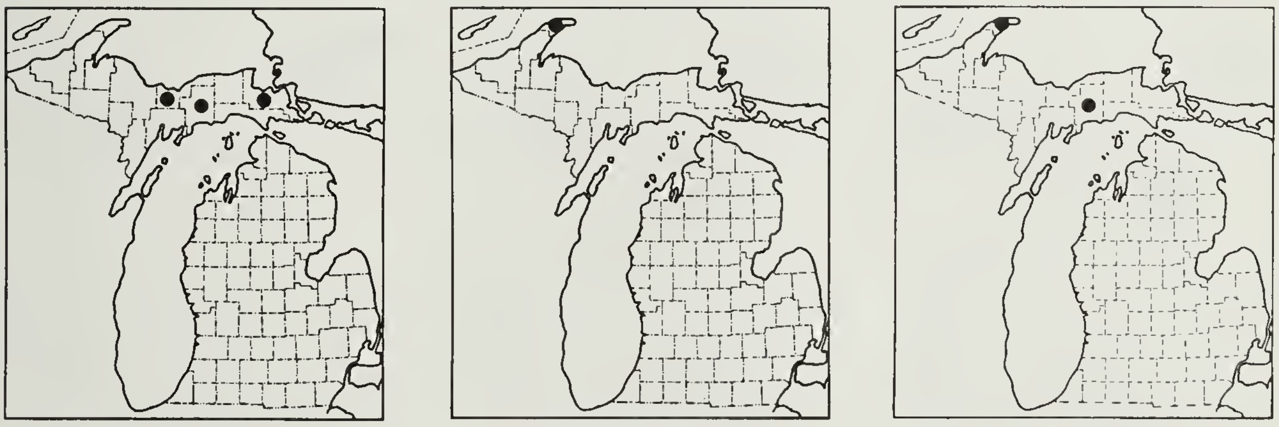
461. Carex typhina



472. Scleria pauciflora

676. Cypripedium candidum

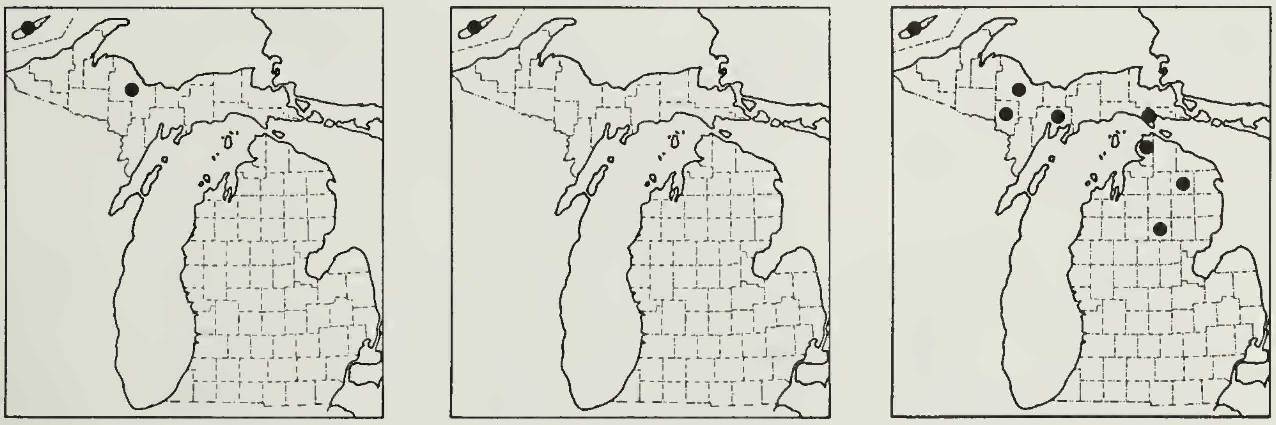
687. Habenaria ciliaris



48. Potamogeton confervoides

208. Phleum alpinum

303. Carex praegracilis

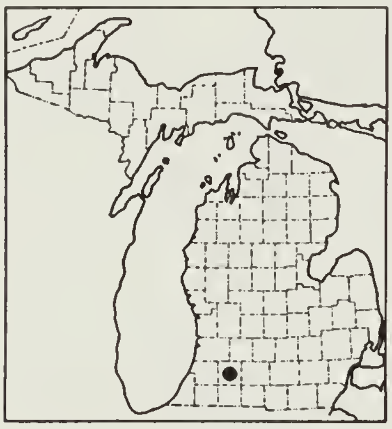


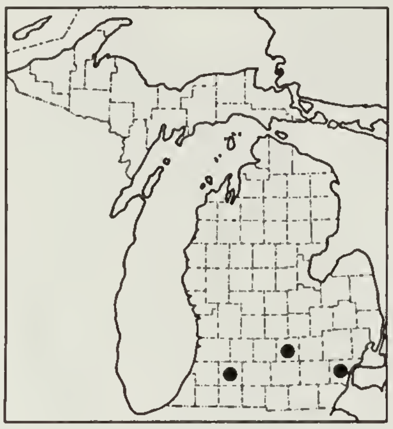
576. Juncus stygius

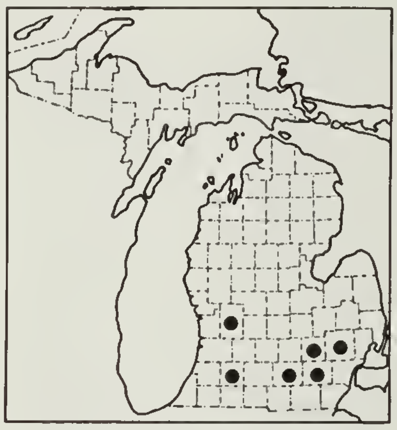
651. Tofieldia pusilla

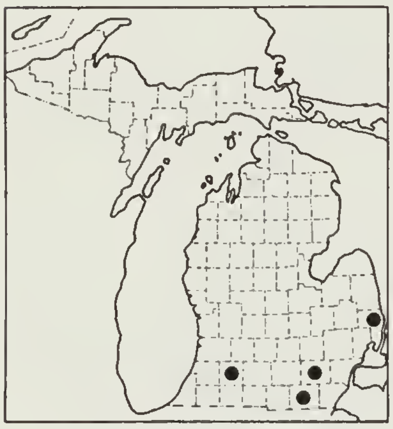
684. Orchis rotundifolia

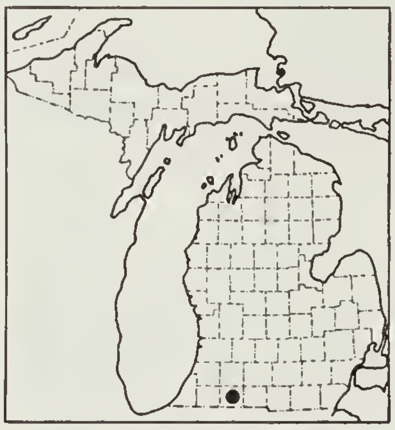
Fig. 4. Top two rows: Selected threatened monocots of aquatic and wetland habitats occurring in southern Michigan. Bottom two rows: Selected threatened monocots of aquatic and wetland habitats occurring in northern Michigan. Maps from Voss (1972), used with permission of Cranbrook Institute of Science.

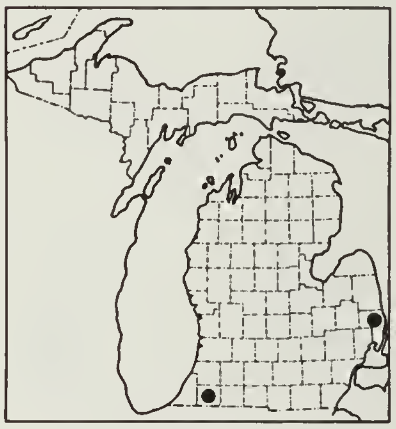

184. Aristida dichotoma

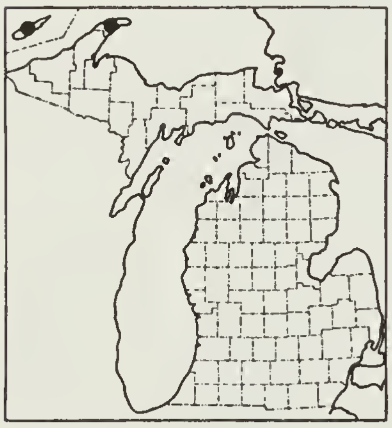

187. Aristida necopina

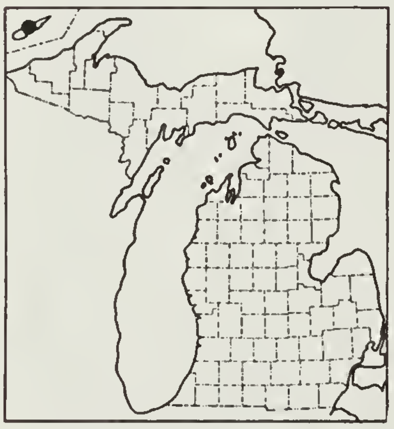

241. Bouteloua curtipendula

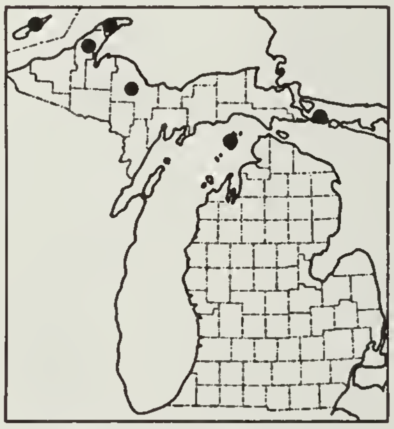

282. Panicum leibergii

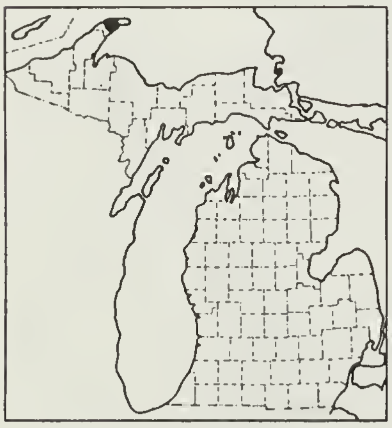

509. Rhynchospora globularis

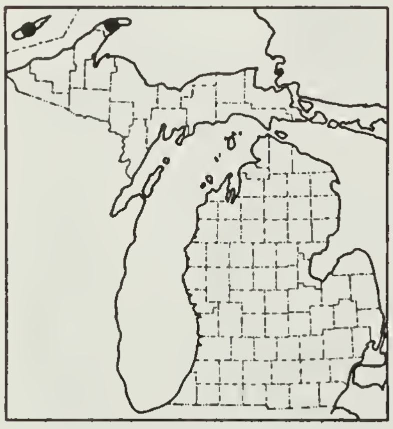

538. Fimbristylis puberula


94. Poa alpina


95. Poa canbyi


169. Trisetum spicatum


372. Carex rossii


436. Carex media

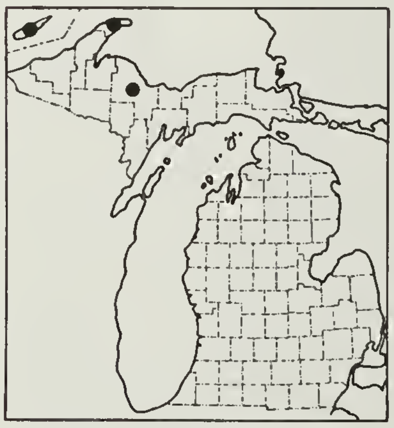
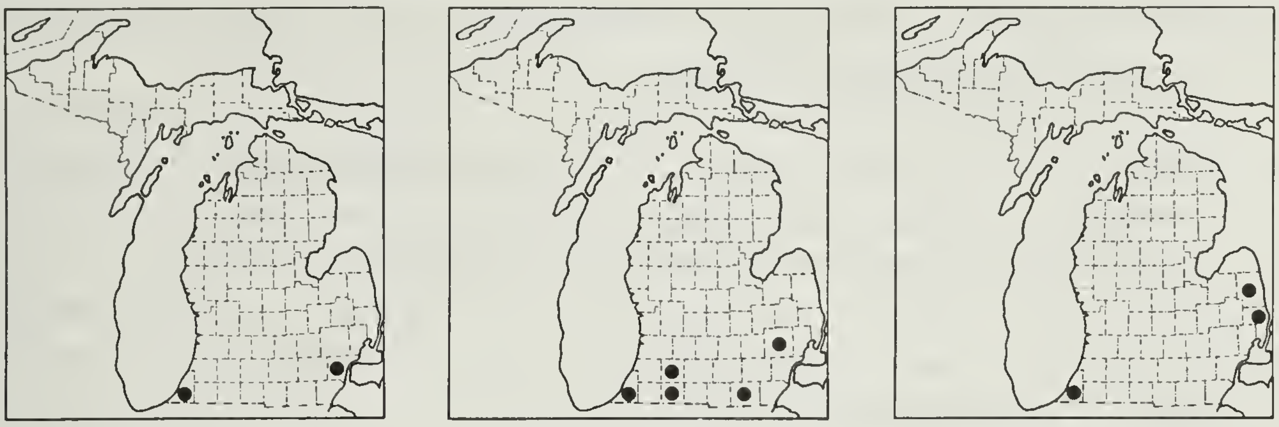

437. Carex atratiformis

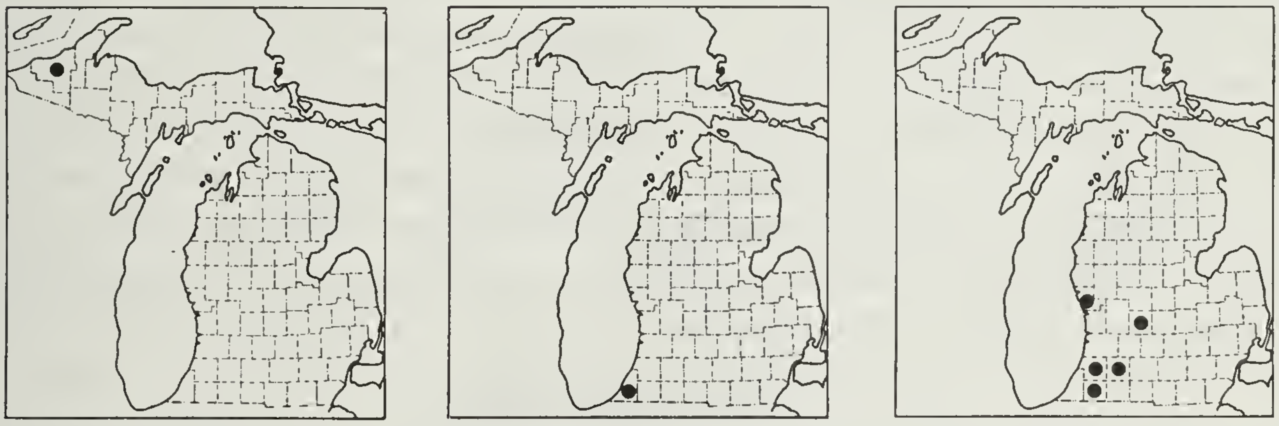
Fig. 5. Top two rows: Michigan distribution of selected threatened monocots of prairie habitats. Bottom two rows: Michigan distribution of selected threatened monocots of rock outcrop habitats. Maps from Voss (1972), used with permission of Cranbrook Institute of Science.



608. Trillium recurvatum

610. Trillium sessile

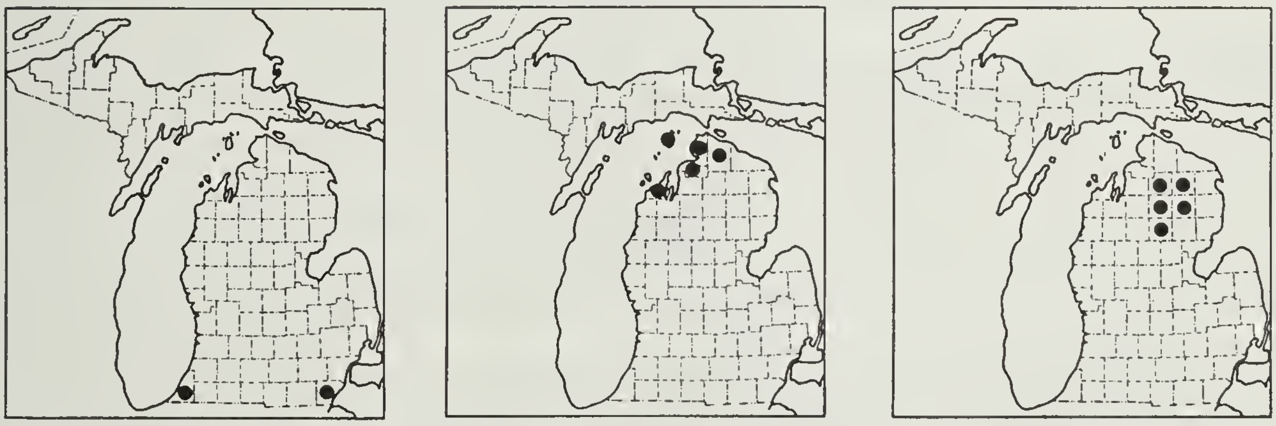
612. Trillium undulatum



639. Disporum hookeri

683. Tipularia discolor

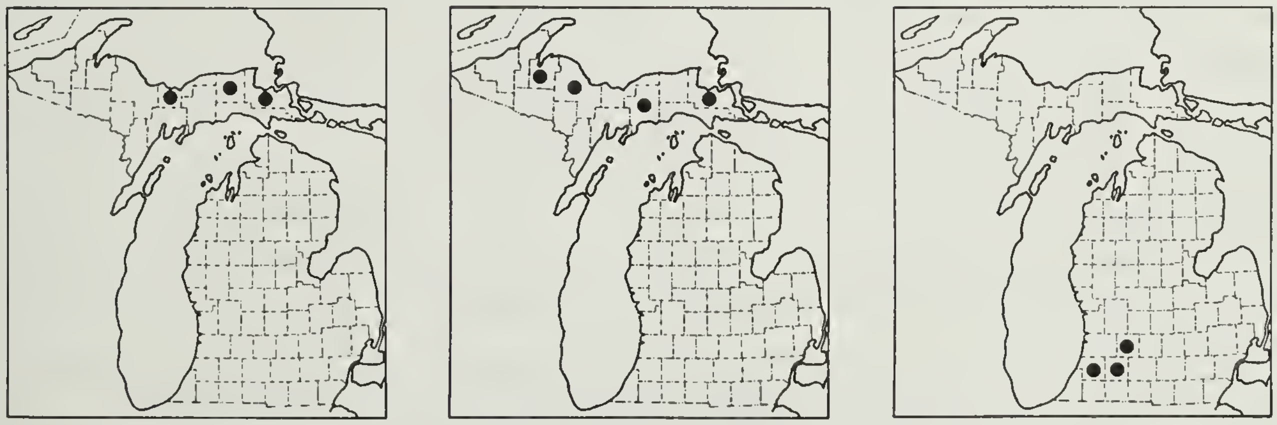
709. Triphora trianthophora



79. Triplasis purpurea

113. Bromus pumpellianus

130. Festuca scabrella



148. Elymus mollis

193. Oryzopsis canadensis

589. Juncus scirpoides

Fig. 6. Top two rows: Michigan distribution of selected threatened monocots of woodland habitats. Bottom two rows: Michigan distribution of selected threatened monocots of dunes and other sandy areas. Maps from Voss (1972), used with permission of Cranbrook Institute of Science.

whether their status is improving or becoming more critical must also be a continuing objective and responsibility.

One of the most important aspects of immediate concern in the rare plants problem is the identification of critical localities where endangered and threatened species occur. When these localities are established, strong efforts must be directed at habitat preservation. There is danger, however, in making knowledge of the locations of rare plants too generally available, because it might be unscrupulously used for personal profit or other motives contrary to best interests in preserving these plants.

Although it may seem that the task of preservation of endangered and threatened species in Michigan has just begun, the list of plants that has been drawn up will have great value for many purposes. Among the most important of these is the evaluation of various environments throughout the state. The list should be especially valuable in the preparation of impact statements, which have been notoriously short on good data concerning plants and which, for any validity, require accurate identifications. The list also brings a common denominator to the assessment of the biological significance of natural areas throughout Michigan.

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SEVERAL INTERESTING FONTINALIS COLLECTIONS IN HOUGHTON COUNTY, MICHIGAN

Janice M. Glime and Stephen E. Trynoski
Department of Biological Sciences,
Michigan Technological University, Houghton, 49931

Fontinalis seems to be the most frequently mentioned of the aquatic mosses, probably because of its large size, wide distribution in the northern hemisphere, and ease of generic identification. But even so, its distributional records indicate large gaps, and its ecological requirements are poorly understood. A survey of Houghton County quickly indicated that Darlington's (1964) *Mosses of Michigan* does not describe the abundance of the genus in the Keweenaw Peninsula of Michigan's Upper Peninsula. Among Steere's extensive collections of Copper Country bryophytes, only *F. antipryetica* var. *gigantea* (Sull.) Sull. was recorded by Welch in her monograph (1960). Crum (1976) questioned the one record of *F. flaccida* Ren. & Card. from Bob Lake (Welch, 1960). In the present study, *F. antipyretica* var. *gigantea* was collected in a tributary to the Pilgrim River near Dodgeville (*Glime 87, 88, 89,* 10 July 1975), three species were added to the flora, and a population suspected of being earlier identified as *F. flaccida* (but possibly referable to *F. dalecarlica*) were located, totalling five species for Houghton County.

Acton (1975) recorded *F. duriaei* Schimp. from several locations in Cole's Creek near Houghton. This species occurred on rocks and wood (*Glime 10,* 31 Oct. 1975; *Glime 18, 19, 20,* 11 Oct. 1975). A search elsewhere resulted in collections from Obenhoff Creek (*Glime 11, 12, 14,* 16 Nov. 1975), where it occurred only on wood, and Big Valley Creek just above the confluence with the Salmon Trout River, where the moss was abundant on numerous fallen logs.

We placed several lake collections into *Fontinalis duriaei* (*Glime 60, 61,* Sand Lake, 10 May 1975; *Glime 65,* Eleven Mile Lake, 10 May 1975; *Glime 66,* stream south of Winona Cemetery, 11 May 1975; *Glime 75,* Dollar Bay, 19 May 1975, and *99,* 10 July 1975). These collections appear to resemble more closely *Fontinalis macmillanii* Card. than *F. duriaei.* Their leaves are both plane and tubular, and occasionally keeled. The tips are sometimes twisted. Their median leaf cells are longer than those of the stream specimens mentioned earlier, ranging 15-30 : 1. The alar cells and apical teeth could fit either species. But characters overlap both species and could fit the broad variability of *F. duriaei.* It appears that the lake specimens might represent an ecotype different from the stream specimens.

Fontinalis duriaei is typically a northern moss and seems to have an optimum temperature near 10°C (Acton, 1975). Big Valley Creek maintained temperatures of 15-17°C during the summer of 1976 (Vacco & Fornwall, unpubl.), and plants of *F. duriaei* growing there became yellow-brown and flaccid. Many plants were stranded out of water. In Cole's Creek, a stand of *F. duriaei* was located in a small feeder stream where a spring seemed to maintain a temperature near 10°C (Trynoski, unpubl.). These plants remained bright-green and healthy-looking all summer. Such behavior was noted in a New Hampshire stream where *F. novae-angliae* and *F. dalecarlica* lost color and vigor in the summer (Glime, personal observation). By the end of winter the New England plants had regained their vigor. This capability was suggested by the bright-green color of Big Valley Creek mosses in June of 1976.

Big Valley Creek also has *Fontinalis neomexicana* Sull & Lesq. This is no misplaced collector's item in Michigan, as suggested by Crum (1976) when he referred to the Manistee County record of E. J. Hill. A distribution in the West from Alaska to New Mexico and east to Montana (Welch, 1960) rightfully caused Crum to question a disjunct occurrence in the Lower Peninsula (Welch, 1960). The record was suggestive of a mislabelled collection or a chance introduction. But a record from Big Valley Creek is no mistake (*Glime 1,* 16 Nov. 1975). The species is common on the many fallen logs in the creek, reaching 20-30 cm-long flowing mats. Often the plants are covered with sand, and the lower leaves are absent because of abrasion. In the summer of 1976 it, like *F. duriaei,* lost its green color, and *F. neomexicana* lost most of its leaves, becoming difficult to recognize. It grew new branches in the fall when the weather and stream temperatures cooled. *F. neomexicana* seemed to occur in deeper water than *F. duriaei,* but this could not be supported statistically owing to the difficulty of identifying unhealthy plants. Both species had numerous plants stranded out of water during the dry summer, and many of these were leafless tufts resembling wire brushes. The occurrence of *F. neomexicana* in the Upper Peninsula makes a considerable range extension eastward, at one of its northernmost locations. Its ability to regenerate through fall growth at a time when this phenomenon did not seem apparent in *F. duriaei* reflects its more southern distribution, where it would be more likely to survive prolonged warm periods. It is possible that more shallow water in 1976 got too warm for the plant and killed its leaves.

Fontinalis patula Card. was found on wood in Pike River (*Glime 49,* 28 April 1975; *Glime 71,* 15 May 1975), Pike Lake (*Glime 26, 52,* 10 May 1975), and Bob Lake (*Glime 105,* 30 April 1976; *Trynoski,* 30 April 1976), and on rock in Gravereat River (*Schwedler,* 14 May 1976). This species has been reported for Keweenaw and Marquette Counties (Welch, 1960). Its collection in several locations in Houghton County is noteworthy because records are scant and the Keweenaw Peninsula represents a disjunt locale. The principal area of distribution is northwestern U.S. and western Canada, as far north as Alaska (Welch, 1960). It is also reported from Connecticut and Cape Breton Island, Nova Scotia. This unusual distribution suggests that more locations are likely to be found in the northern U.S. and Canada, unless some unusual habitat parameter restricts its distribution.

To complete our study of interesting Houghton County *Fontinalis* records, we visited Bob Lake in an attempt to verify the occurrence of *F. flaccida* Ren. & Card. (Welch, 1960). We were surprised to find two species of *Fontinalis* immediately upon entering the water at the recreation site, and one of these was a limp moss which we thought was certain to be the *F. flaccida* in question. However, close examination failed to reveal the distinct auricles typical of *F. flaccida,* and its leaves were sometimes flat and sometimes rolled.

Crum (pers. comm.) determined the moss to be *F. dalecarlica* BSG, an equally interesting find. The pliable stems were unlike any *F. dalecarlica* we have seen, but perhaps this is an ecotypic response to the lake habitat when all our previous observations have been in streams.

If *Fontinalis flaccida* did occur here, it would indeed be an interesting find. Its distribution is confined to the eastern U.S. and Canada, with Bob Lake standing out as the only disjunct and more western location. We feel that we might have been looking at the same clone of plants already reported for Bob Lake as *F. flaccida,* and on the basis of our specimens we are not ready to say for sure if these are ecotypes of *F. dalecarlica* or *F. flaccida,* or perhaps even something else.

F. dalecarlica enjoys a distribution on both sides of the Atlantic but seems to be confined to the eastern half of the U.S. and Canada (Welch, 1960). It ventures into Wisconsin and Minnesota, and so it should be expected here, but no previous Upper Peninsula records are known. We have found it in Black River near county road 478, 4.4 miles from Republic, Marquette County (*Trynoski,* July 1975; *Glime 100,* 4 August 1975), where it grows profusely on rock under the bridge. If the plants in Bob Lake are *F. dalecarlica,* it would not be unexpected.

Houghton County and the Keweenaw Peninsula in general appear to have a rich variety of *Fontinalis* species, where northernmost and southernmost reaches of their ranges bring them together. This is not surprising in an area where forests are a patchwork of mixed forest, hardwoods, hemlocks, boreal forest, and pine barrens (Wells & Thompson, 1974), attesting to the ecotonal nature of the region. The presence of vascular plant disjuncts in the Keweenaw Peninsula is not unusual. Among them are plants which occur only in the West and in Keweenaw County. It is not surprising that *Fontinalis* should be represented by species from those same regions.

We appreciate the assistance of Dr. Howard Crum, who confirmed several of our identifications. Specimens verified by him are in the University of Michigan Herbarium.

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ADDITIONS AND CORRECTIONS TO THE LIST OF VASCULAR PLANTS FROM THE DOUGLAS LAKE REGION, MICHIGAN

Edward G. Voss
Herbarium, University of Michigan, Ann Arbor, 48109

Botanical studies at the northern tip of the Lower Peninsula of Michigan began long before the establishment of the University of Michigan Biological Station on Douglas Lake in 1909. However, since 1909 special efforts have been made to keep records of the local flora, and the "Douglas Lake Region" came to be defined as Emmet and Cheboygan counties, which share the tip of the Lower Peninsula and which provide precise, even if arbitrary, boundaries for the area under consideration.

Some 20 years ago (1956) I presented a history of floristics in the region, including an account of published records which could not be accepted because of failure to find any correctly identified voucher specimens. A companion paper listing additional species known in the regional flora was prepared at the same time (published 1957). These papers supplemented the basic Gates and Ehlers[1] list for the Douglas Lake Region (1925; additions 1928, 1931, 1948) and took into account published literature and herbarium specimens not necessarily related to work done in association with the Biological Station.

The time seems ripe for a new supplement, while admitting that such a patchwork approach to an old list is less satisfactory than a complete new one, which time does not yet permit preparing. During the two decades since the previous list of additions, staff[2] and students at the Biological Station have continued to add to our knowledge of the local flora; and the first part, treating gymnosperms and monocots, of my *Michigan Flora* has appeared (1972). Preparation of the *Flora* meant intensive taxonomic investigations and herbarium studies, with resulting reidentifications and realignments for certain taxa.

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[1] John H. Ehlers taught courses in plant taxonomy at the Biological Station from 1916 until his retirement in 1938 (at the age of 70)—never having missed a day of class, he told me when he returned to Douglas Lake for the semicentennial celebration of the Station in 1959, and I was privileged to visit with him and show him the station herbarium. He died in 1967, shortly after his 99th birthday. Frank C. Gates (1887-1955) taught plant ecology at the Station 1915-1954 (see Voss, 1956, pp. 21, 38-39).

[2] Taxonomy of Flowering Plants was taught at the Biological Station by Elzada U. Clover in 1954 and from 1956 through 1966, when she retired. In 1967, I expanded this program into two courses (partly concurrent), offering Taxonomy of Flowering Plants as a 10-week course through 1974 (except for 1970) and Boreal Flora continuously (except for 1975). In 1975 and 1976, John W. Thieret offered Taxonomy of Flowering Plants. Aquatic Flowering Plants was taught by F. K. Sparrow 1956-1962 and by me 1963-1969 and 1971. Robert R. Haynes was the 1973, 1975, and 1977 Aquatics instructor, having served as teaching assistant in that course in 1971 and in Taxonomy and Boreal Flora in 1972 and 1973 (for many of my 1971-1973 collections, he was a willing accomplice).

In the list which follows, names of species to be deleted from the regional flora appear in square brackets (immediately above a reidentification if that is the situation). Insofar as the monocots are concerned, the deletions and additions will bring the published list into accord with records indicated on distribution maps in *Michigan Flora* (plus subsequent discoveries). In general, the format of the previous list is followed: the county or counties from which a new record is being reported are indicated by initials at the right margin (E. = Emmet Co.; C. = Cheboygan Co.). Only species new to the entire region (not those already known from one of the two counties) are included. A few records of unusual forms worthy of note, although the species are not new, are mentioned in addition. In contrast to previous lists, more complete citations are given for collections of all but the commonest species, including collector and number with year of collection. Herbaria where sheets have been examined (or to which they have been distributed by me) are indicated by the standard symbols of *Index Herbariorum* (plus 'EGV' for my personal herbarium, at Mackinaw City), as listed also in previous accounts (1956, p. 49; 1957a, p. 6; 1972, p. 9).[3] When collections are cited from both counties, those for Cheboygan County follow those for Emmet County, after a dash. Localities are generally given as they appear on labels, whether political or survey townships are specified (or neither). The maps (pp. 18-19) and account of collectors in my 1956 history should be helpful, supplemented by the brief post-1956 history in footnote 2 of the present paper.

Changes of name as a result of taxonomic and nomenclatural adjustments are usually not recorded here, as the disposition of records should be clear from *Michigan Flora* or other basic sources. As in the 1956 and 1957 papers, no attempt has been made to call attention to previously misidentified material reported from the region (either county) if other collections support the occurrence of the species in either of the two counties, as this is a supplement to the *regional* list as a whole without regard to details within the region. It would take more space than could be justified to elaborate all the local additions and subtractions. A number of the species reported as new to the region in 1957 have now been found at additional stations, often in both counties, but they, too, are not listed here. On the other hand, some species once collected in the region were undoubtedly casual waifs, not again found; leaving them in the record suggests, at least, that they might be found again.

The total number of species known authentically from the two counties was given in 1957 as 1180. There will always be differences of taxonomic opinion as to recognition of species, as well as doubts about the authenticity of particular records; but as a result of additions and subtractions and also of changing the status of a few previous records by lumping (e.g. *Lolium*

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[3] In my previous list of additions (1957a) it was stated that institutional herbaria were indicated by this international standard, and yet "MSU" rather than "MSC" appeared throughout the paper for the herbarium of Michigan State University. This change was made editorially at the University of Michigan Press *after* I had marked proof and entirely without consulting me.

multiflorum, Scirpus atrocinctus) or splitting (e.g. *Agrostis stolonifera, Panicum lindheimeri, Carex cryptolepis*), the total count for the region can now be given as 1256 indigenous and non-indigenous species (not counting named hybrids, varieties, or forms). Further refinements, especially in the dicots, may be expected in future years.

Except for some obvious garden escapes, species previously unreported from Michigan, or particularly rare in the state, are generally provided with remarks below on their status throughout the state or at least in the Straits of Mackinac area.

Asplenium platyneuron (L.) Oakes C.

One large plant of ebony spleenwort, from which a single frond was collected, was found on the Biological Station campus in 1958 but had disappeared by 1960 (Piehl 58284, MICH—see Piehl, 1964, p. 40).

[*Sparganium fluctuans* (Morong) Robinson]

The specimens earlier reported (1957a, p. 9) as this species have been reidentified as a semi-terrestrial form of *S. angustifolium* (see Voss, 1972, p. 74). *S. fluctuans* is not known south of the Straits of Mackinac (or even near it—see Voss, 1965, map 3; 1972, map 19).

[*Sparganium simplex* Hudson]

Reported by Gates and Ehlers from Bessey Creek, but the only specimens so labeled (Ehlers 1085, MICH, MSC) are *S. chlorocarpum.* (The name *S. simplex* was once misapplied to *S. multipedunculatum,* a species which does not range into Michigan.)

Potamogeton hillii Morong E. C.

Proposed for listing as "threatened" under both Federal and State endangered species legislation, this pondweed seems to be concentrated in northern Michigan. There are now a number of records from the Douglas Lake region, some of them collected earlier but not recognized at the time of my first discussion of this species (1965, pp. 13-15). Big Sucker Creek, Wilderness State Park (Sparrow in 1950, MICH); marsh in Cecil Bay between mouths of French Creek, ca. 4 mi. SW of Mackinaw City (J. Ludwig in 1971, UMBS; Voss 14061 in 1972, MICH, UMBS, MSC, BLH, GH, NY, WIS, CAN, LKHD, OS, US, EGV), the only location in the waters of the Great Lakes themselves.—North end of the Twin Lakes, sec. 34, T37N, R1E (Wood in 1951, UMBS; Haynes 5228 in 1975, MICH); western Twin Lake, sec. 2, T36N, R1E, ca. 12 mi. SE of Cheboygan (Haynes 5097 in 1975, MICH); ditch and backwaters at Elliotts Creek, sec. 35, T38N, R1W, ca. 4 mi. E of Cheboygan (Voss 11350 in 1963, MICH, UMBS, EGV; 12735 in 1968, MICH, MSC, UMBS, EGV; Haynes 3389 in 1970, MICH). The Elliotts Creek plants were originally thought to be a form of *P. obtusifolius* with more obscure glands and more acute leaves than usual for that species. All collections cited have been determined by Robert R. Haynes (see also Haynes, 1974, pp. 606-612).

Potamogeton nodosus Poiret C.

Reported (1965, p. 11) from the Black River, which remains the only known station in the northern half of the Lower Peninsula. First found (Voss 11240 in 1963, MICH, UMBS, EGV) in a large bay in the SW¼ sec. 15, ca. 3 mi. NW of Alverno, but colonies subsequently noted at other localities downstream, to near the mouth of the Black River.

Potamogeton oakesianus Robbins C.

Numerous collections from Smith's Bog and Nichols Bog, from 1940 onwards (MICH, UMBS, BLH, OS, EGV).

[*Potamogeton perfoliatus* L.]

The collection cited (1957a, p. 10) to justify retaining this on the list was identified in 1959 by E. C. Ogden as *P. richardsonii.* Subsequent years of observation of the plants in the Black River confirm that the latter is a variable species, often with very short leaves in this locality.

Potamogeton pulcher Tuckerman C.

This pondweed has turned out to be rather common in East Lake (one of the Twin Lakes ca. 5 miles S of Mackinaw City), sec. 7, T38N, R3W, the second locality known for Michigan. Whether it is a recent immigrant or has been overlooked for many years is not known (see also *Scirpus torreyi,* below). First collected in East Lake in 1971 (S. Galen Smith 71-121, UMBS; 5031 & 5351, MICH; Voss 13626, EGV).

Potamogeton pusillus L. var. *pusillus* E.

Typical *P. pusillus* (as distinct from var. *tenuissimus* = *P. berchtoldii*) is found in a small arm from Carp Lake in sec. 23, Carp Lake Tp., ca. 1½ mi. SE of the village of Carp Lake (Voss 11561 in 1964, MICH, UMBS, EGV; Haynes 3370 in 1970, MICH—see also Haynes 1974, p. 632).

Potamogeton spirillus Tuckerman C.

Previously (1956, p. 51) deleted from the list because no specimens from the original and likely locality reported, Lancaster Lake, had been found and the only one labeled as *P. spirillus* was in fact *P. gramineus.* The species may now be restored to the list on the basis of a small specimen from ca. 0.5 m water on the east side of Vincent Lake (A. Schwartz & J. Kushner in 1968, UMBS).

Najas guadalupensis (Sprengel) Magnus C.

Douglas Lake (R. M. Johns in 1948, MICH); Indian River (C. Peikert n.d. [ca. 1945], UMBS); bay of Black Lake W of mouth of Upper Black River (Stuckey 3273 in 1966, OS; Voss 12371 in 1966, MICH, UMBS, EGV); Black River near its mouth (Voss 12495 in 1967, UMBS).

Elodea nuttallii (Planchon) St. John E.

This is another species previously (1956, p. 51) dropped from the list because earlier collections were all misidentified, but now restored. Found in Carp Lake, where it is especially abundant in a small arm off the south shore in sec. 23, Carp Lake Tp., ca. 1½ mi. SE of the village of Carp Lake. First collected in 1964 (Voss 11554 & 11560, MICH, UMBS, MSC, BLH, EGV); determination confirmed by H. St. John in 1966. All plants seem to be staminate, the spathes with a globose body ca. 2-2.5 mm long, sessile even after discharge of stamens; readily distinguished vegetatively from *E. canadensis,* both sexes of which grow with it.

[*Agrostis tenuis* Sibth.]

Reported (as *A. capillaris* L.) by Gates and Ehlers (1925) from the banks of Bessey Creek, said to be determined by Hitchcock, and (1948) from Wycamp Lake, 1931. The latter material (Gates 16622, GH) is actually *Muhlenbergia uniflora.* No specimens purporting to be this species from Bessey Creek (or anywhere else in Cheboygan Co.) have been found in Michigan herbaria and none were found filed under *A. tenuis* in the U.S. National Herbarium.

Avena fatua L. C.

One collection originally called *A. sativa* has been referred here: By old sawmill on shore of Burt Lake (M. Robertson in 1912, UMBS). The long, bent awn is strongly twisted, and there are stiff hairs on the lemma.

[*Eragrostis frankii* Steudel]

Eragrostis pectinacea (Michaux) Nees E.

The collection reported by Gates and Ehlers (1931) as *E. frankii* from the millyard at Pellston (Gates 15370 in 1928, UMBS) seems better referred to *E. pectinacea* although the spikelets are smaller than usual (some as many as 6-flowered), on the basis of its larger lemmas, strongly ascending pedicels, and strongly 3-nerved lemmas.

Festuca arundinacea Schreber E.

Occasional in disturbed ground along road at edge of woods on southern village limits of Mackinaw City (Voss 14842 in 1976, MICH, UMBS, MSC, BLH, LKHD, EGV).

Lolium temulentum L. C.

Necessarily excluded (1956, p. 52) because specimens had not been seen to support the Gates and Ehlers (1948) listing. The only extant material has been lent me by LeRoy H. Harvey from his personal herbarium: Wet clay, edge of Cheboygan dump, mixed in clumps of *Phalaris canariensis,* sec. 30, T38N, R1W, in 1938.

Panicum lindheimeri Nash E. C.

This species was tentatively merged with *P. implicatum* in my 1956 report, which noted that its occurrence in both counties was apparently supported by good material. Since in *Michigan Flora* this is tentatively recognized, the assurance should be repeated that it is a frequent grass in our region on sandy shores of lakes, in beach meadows, and around beachpools (at least 15 collections).

[*Poa languida* Hitchc.]

The collection earlier reported (1957a, p. 13) as this species is *P. saltuensis,* already known from several sites in the region.

Poa paludigena Fern. & Wieg. C.

Labeled as a weed near Bryant's Hotel and Cottages (Coburn & Dean 77 in 1928, UMBS). Originally determined as *P. palustris,* but the ligules and anthers are too short for that species. Bryant's Bog would be a more probable habitat for this infrequent plant of bogs and swamps, proposed as "threatened" under the Federal endangered species act.

[*Poa sylvestris* Gray]

The only collection in support of the Gates and Ehlers report (1925), from Pine Point (M. Robertson in 1912, UMBS), is *P. pratensis.*

Carex alopecoidea Tuckerman· C.

Scarce in sedge meadow, sec. 34, Grant Tp. (Marshall 714 in 1949, MSC). Northernmost record for the state.

Carex atlantica var. *incomperta* (Bickn.) F. J. Herm. C.

Pine Point Bogs, Douglas Lake (Ehlers 745 in 1918, UMBS); originally as *C. sterilis* but determined by Hermann in 1965.

Carex blanda Dewey E.

Previously excluded (1956, p. 54), but a collection originally labeled as *C. laxiflora* has been placed here by Hermann: Paige (Fallass in 1914, ALBC).

Carex foenea Willd. C.

One collection from "Jack Pine Plains" and hence from Cheboygan County east of Petoskey, where other notes of C. W. Fallass confirm that he collected on the same day (June 29, 1922); originally labeled as *C. diandra* (Fallass 782, ALBC), referred to *C. foenea* by Hermann in 1959.

Carex gynandra Schw. E. C.

Not previously listed (except by Hermann, Am. Midl. Nat. 25: 58. 1941) because not distinguished from *C. crinita.* It does, however, seem to warrant recognition as a distinct species and is probably as frequent in our region as true *C. crinita.* Boggy thicket near West Branch Maple River ca. 6 mi. W of Pellston (Voss 12255 in 1966, MICH, UMBS, EGV.–Nine collections from Carp Creek, the "Gorge," and Reeses Bog.

Carex sartwellii Dewey C.

Locally abundant in marsh along Berry Creek near center S edge sec. 3, Mentor Tp., ca. 4 mi. SW of Indian River (Voss 14850 in 1976, MICH, UMBS, MSC, EGV; det. confirmed by Hermann, 1977). It is embarrassing to admit that not until 1976 was this species recognized at the edge of the jack pine plains in a marshy area where Biological Station botanists have explored for over half a century (see Ehlers, Rhodora 23: 200. 1921; Anderson, Rhodora 35: 158. 1933; Voss, Am. Midl. Nat. 51: 90. 1954). The only other Michigan record from north of Saginaw Bay is from Drummond Island.

Carex tenuiflora Wahl. E.

Under *Thuja* on bog mat south of Galloway Lake, ca. 1 mi. N of Levering (Voss 12662 in 1968, MICH, EGV, det. confirmed by Hermann; 14821 in 1976, MICH, UMBS, MSC, LKHD, EGV); local, with *C. gynocrates,* in spruce-cedar-tamarack bog, NW¼ sec. 25, T35N, R5W, ca. 1 mi. S of Conway (Voss 13561 in 1971, UMBS).

Cyperus esculentus L. C.

Local, with *Butomus umbellatus* in a moist hollow at the western city limits of

Cheboygan, on S side of Lincoln St., near High School (Voss 12502 in 1967, MICH, UMBS, EGV).

Eriophorum gracile W. D. J. Koch E. C.

Locally common in open wet area, spruce-cedar-tamarack bog, NW¼ sec. 25, T35N, R5W, ca. 1 mi. S of Conway (Voss 11960 in 1965, MICH, UMBS, EGV).–In very wet sphagnum in a small bog in aspen woods just SW of bridge over Carp Creek, sec. 4, T36N, R3W (Wood 8143 in 1953, MICH, UMBS).

Scirpus fluviatilis (Torrey) Gray C.

Local at NW edge of a swale ("Sparrow Swale") near center W edge sec. 23, Hebron Tp., ca. 9 mi. SE of Mackinaw City (Voss 11353 in 1963, MICH, UMBS, EGV).

Scirpus torreyi Olney C.

West shore of East Lake (one of the Twin Lakes ca. 5 mi. S of Mackinaw City), sec. 7, T38N, R3W (Schuyler 404 in 1958, MICH; Voss 11746 in 1964, MICH, UMBS, EGV; Stuckey 3138 in 1966, OS; S. G. Smith 71-119 in 1971, UMBS). Like *Potamogeton pulcher,* this species has appeared in some abundance at the very part of East Lake long examined by botanists from the Biological Station (see description by Gates, Ecol. Monogr. 12: 230. 1942). One cannot help wondering whether indigenous species are still invading northern Michigan, when species are found such as these and others reported here from old familiar sites.

Tradescantia ohiensis Raf. C.

A single plant in gravelly soil at edge of woods, S½ sec. 18, Hebron Tp., by road near Carp Lake (Voss 12026 in 1965, MICH). The flowering specimen was collected, and the species has not again been seen; certainly a waif or escape from cultivation so far north (only one other collection known north of Saginaw Bay).

Convallaria majalis L. E.

SW¼ sec. 17, T35N, R5W (Schachinger 18 in 1969, ALM). The locality would be the vicinity of Roaring Brook, where–as elsewhere–the lily-of-the-valley is rather aggressive in spreading from cultivation.

Ornithogalum umbellatum L. C.

Locally established near grassy roadside, E edge sec. 30, Mackinaw Tp., ca. 3 mi. SSE of Mackinaw City (Voss 12484 in 1967, MICH, UMBS, EGV).

Iris lacustris f. *albiflora* Cruise & Catling E.

Typical blue f. *lacustris* of the dwarf lake iris has, of course, long been known from the region, but the presence of the albino form should be noted, especially since the original description (Rhodora 74: 271. 1972) asserts that it is "known only from the type collection" (Bruce County, Ontario). *Michigan Flora* was published the same month as this description and observed: "White flowers are very rarely found." In 1962, H. S. Veltman provided me with what appears to be the first actual specimen (Voss 10833, MICH), from Waugoshance Point in Wilderness State Park. Don Henson has provided color photographs taken in 1973 and 1974 of plants near Lake Michigan in western Schoolcraft County. T. L. Mellichamp discovered a colony near the north edge of Wilderness State Park and provided a color photo taken in 1972; specimens have been made (Voss 14822 in 1976, MICH, UMBS). In 1975 I photographed plants about a mile inland from Sturgeon Bay, at a colony known to Wilderness State Park personnel. Other colonies are surely known to individuals who justifiably refrain from providing details about a rare form of a "threatened" species. The flowers are indeed handsome, with a pure white perianth except for deep yellow in the two grooves of the crest on the sepals. White-flowered plants grow among blue ones and are indistinguishable vegetatively.

Corallorhiza trifida Chat. var. *trifida,* albino form E.

A single plant growing near normal greenish yellow ones, in damp thicket of *Thuja,* etc., near the eastern border of Wilderness State Park (Voss 14824 in 1976, MICH, specimen plus color photo). The perianth and stem when fresh were entirely pure white except for purplish dots on the basal half of the lip, one or two dots toward the base of the lateral petals, and dots and streaks on the column. An albino form of the early coral-root seems not to have been described (and is not mentioned by Luer, 1975); in view of the particular interest many people have in our native orchids I am calling attention to it here. However, I share the oft-quoted reluctance of Asa Gray (see *Michigan Flora,* p. 26) to burden the literature with a formal name for every white-flowered variant (including several other species with unnamed white-flowered forms in northern Michigan).[4]

Epipactis helleborine (L.) Crantz C.

This, our only non-native species of orchid, continues to turn up at new places in the state. George Kopp noted a single plant along an old trail road in his beech-maple-hemlock woods, sec. 8, Tuscarora Tp., ca. 5 mi. NW of Indian River, in 1973. The next year, nearby, a single solitary plant and a clump of three stems (one of which was collected) appeared (Voss 14500, UMBS). The colony can be expected to spread. The species was collected at the Horton Bay Club in neighboring Charlevoix County in 1976 by R. S. Teesdale, who reports it as locally common (MICH).

Spiranthes casei Catling & Cruise C.

S. vernalis Engelm. & Gray was "very tentatively" admitted to the flora of the state (Voss, 1972, pp. 461-463), including one collection from Devereaux Lake, Cheboygan Co. (Voss 509 in 1948, MICH). This collection and some others (from Gogebic, Houghton, Marquette, and Schoolcraft counties, originally referred to *S. cernua*) were examined by Catling in 1973 and annotated as *S. vernalis.* However, in 1975 (Rhodora 76: 526-536. "1974"), Catling and Cruise published the new name *Spiranthes casei* for the controversial "northern *vernalis.*" Luer (1975, p. 108) included "northern *vernalis*" with *S. intermedia,* originally described by Ames as a hybrid from Massachusetts.

[*Spiranthes tuberosa* Raf.]

Correll's attribution of this species to Michigan (Cheboygan Co.) was cited in my 1957 list of additions, but the specimens are almost certainly *S. lacera* (see *Michigan Flora,* p. 460). The species is not mapped closer to our area than southern Ohio and southern Indiana by Luer (1975, p. 109).

Salix pyrifolia Andersson C.

The original report by Gates and Ehlers was excluded (1956, p. 56) for lack of specimens. The species can now be restored to the list on the basis of a different collection (Gates 404 in 1911, MSC), originally identified as *S. discolor* × *rostrata* but referable to the northern balsam willow by the persistent balsamic odor, glabrous red twigs, and shape and texture of the leaves. Gates' published report citing this number (Rep. Mich. Acad. 14: 89. 1913) apparently considers more than this collection, which is from hardwoods, edge of Lake, N of Douglas Lake, according to Gates' 1911 field notes.

Polygonum cuspidatum Sieb. & Zucc. E.

A bushy herb occasional in waste ground at the old Mackinaw City dump, near center N½ sec. 13, Wawatam Tp. (Voss 7944 in 1958, MICH, UMBS, EGV); noted (but not collected) in 1976 at the present Mackinaw City dump site; noted also by W. J. Gilbert in 1976 at Bay View. Filled ground at SW end of McManus Dam, Petoskey

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[4] There seems to be no name for white-flowered *Lathyrus japonicus* var. *glaber* (Ser.) Fern., although Fernald named albinos in other varieties of this species (Rhodora 42: 157. 1940); such plants have been seen on the Grand Sable dunes (Alger Co.) and elsewhere. *Teucrium canadense* var. *occidentale* (Gray) McCl. & Epl. likewise seems to lack a name for an albino form (although typical var. *canadense* has f. *albiflorum* House); both white and normal forms grow on the shore of Munro Lake (Voss 11364 in 1963, MICH). A white-headed form of *Cirsium hillii* (Canby) Fern. grows with the normal form on the jack pine plains in Ellis and Koehler Tps. (Voss 1321 in 1952, MICH). The name *C. pumilum* var. *hillii* f. *candidum* Boivin (Nat. Canad. 94: 646. 1967) is an illegitimate homonym under Art. 64 of the International Code of Botanical Nomenclature, being antedated by *C. pumilum* [var. *pumilum*] f. *candidum* Fern. (Rhodora 45: 354. 1943); if *C. hillii* is treated as a species distinct from *C. pumilum,* then any epithet for an albino form of it may be published as new, including *candidum* (but not as a transfer of Boivin's illegitimate epithet—see Art. 72).

(Tanton in 1967, MICH, UMBS); immediately W of Little Traverse Hospital (Tanton in 1967, MICH). Piehl (1964, p. 42) alluded to Emmet County records but gave no details.

[*Chenopodium bonus-henricus* L.]

Cited by Gates and Ehlers from Cecil and North Fishtail Bay. The former material (Ehlers 218 in 1916, MICH) is *C. hybridum* (seeds all horizontal, inflorescence paniculate); the latter (Ehlers 1786 in 1921, MICH, UMBS) is *C. capitatum* (with short slender styles, although the leaves are unusually entire).

Chenopodium glaucum L. C.

City dumping ground, Cheboygan (Ehlers in 1936, UMBS, without number or identification); locally frequent on moist stony shore of Straits of Mackinac in NW part of Cheboygan, sec. 30, T38N, R1W (Voss 11346 in 1963, MICH, UMBS, EGV). Our specimens are evidently var. *salinum* (Standley) Boivin, with distinct acute teeth, often recognized as a separate species.

[*Chenopodium leptophyllum* (Moq.) S. Watson]

Chenopodium subglabrum (S. Watson) A. Nelson E.

The material previously reported (1957a, p. 18) as *C. leptophyllum* can be better referred to *C. subglabrum.* The plants are lightly farinose with very narrow 1-nerved leaves; the pericarp is readily separable from the seed, which is distinctly more than 1 mm in diameter. (*C. leptophyllum,* in a narrower sense, is densely farinose and the seeds are smaller with adherent pericarp. See Wahl, Bartonia 27: 15. 1954; Crawford, Brittonia 27: 282. 1975.) Plants of this species have not been seen in the region for a number of years.

Corispermum hyssopifolium L. C.

Locally frequent, sand bank above gravel road, SE corner sec. 23, Inverness Tp., ca. 5 mi. SSW of Cheboygan (Voss 14526 in 1974, MICH, UMBS, EGV, MSC, BLH, LKHD).

[*Gypsophila acutifolia* Sprengel]

Gypsophila scorzonerifolia Ser. C.

The material previously reported (1957a, p. 19; 1957b, p. 91) as *G. acutifolia* should be referred to *G. scorzonerifolia* (see Pringle, Mich. Bot. 15: 215-219. 1976). An additional Michigan collection of this species has been seen from roadside near Traverse Lake, Cleveland Tp., Leelanau County (Thompson L-326 in 1947, BLH).

Saponaria ocymoides L. C.

This species spontaneously became well established on the sandy fill in front of the new Lakeside Laboratory at the Biological Station (Voss 12488 in 1967, MICH, UMBS, EGV). Now becoming much less common as other plants have crowded it out.

Aquilegia vulgaris L. E. C.

One plant, edge of *Thuja* woods near road along Little Traverse Bay ca. 3½ mi. E of Harbor Springs (Voss 12659 in 1968, MICH); seen here again in 1969; plants with pure white flowers, not "double."–Occasional in disturbed ground near Douglas Lake on W side of Lakeside Laboratory, Biological Station (Voss 13829 in 1972, UMBS); all plants of the garden columbine established here have had the flowers pink and "double."

Berberis thunbergii DC. E.

The Japanese barberry was found as a shrub in aspen woods near the center of sec. 8, Bear Creek Tp., ca. 1 mi. S of Petoskey (Voss 12046 in 1965, with J. Tanton, MICH, UMBS, EGV).

Berberis vulgaris L. E.

A solitary large bush of the common barberry was found ½ mi. W of Pellston, along Maple River (Stuckey in 1961, MICH, UMBS); it could not be found when sought again in 1973, according to the collector (pers. comm.).

Chelidonium majus L. E.

Established for a few years in an abandoned portion of the Levering dump, NW¼ sec. 1, McKinley Tp., ca. 2 mi. E of Levering (Voss 12866 in 1969, MICH, UMBS, EGV).

Diplotaxis muralis (L.) DC. E.

Previously (1956, p. 59) deleted from the list in the absence of any correctly identified material. Now to be restored on the basis of a collection from the rocky bank of Bear Creek at waste area, ca. ¼ mi. SW of Petoskey, sec. 6, T34N, R5W (Mellichamp 1262 in 1971, UMBS).

Erysimum inconspicuum (S. Watson) MacM. C.

Edge of Sturgeon River, Wolverine (Dreisbach 7769 in 1932, MICH, UMBS); mixed collection with *E. cheiranthoides.*

Nasturtium microphyllum (Boenn.) Reichenb. E.

Two collections in UMBS originally identified as the diploid *N. officinale* have been determined as this tetraploid species by R. L. Stuckey; duplicates of both are in MICH: Border of cold spring, Alanson (Ehlers 5110 in 1932); marly flats back of beach, Little Traverse Bay, 3 mi. E of Harbor Springs (McVaugh 10785 in 1949). A collection from Pickerel Lake (Gleason 100 in 1933, GH) was cited by Green in his discussion (Rhodora 64: 32-43. 1962) of these species of watercress, which have often not been distinguished.

Rorippa sylvestris (L.) Besser E.

Scarce in moist rocky ground along Crooked Lake, S edge sec. 15, Littlefield Tp. (Voss 2380 in 1954, UMBS, SMU); cited by Stuckey (Sida 2: 372. 1966).

Sedum album L. E.

Local, established on upper sandy beach with the locally common *S. acre,* shore of Little Traverse Bay ca. 3½ mi. E of Harbor Springs (Voss 12493 in 1967, MICH, UMBS, EGV).

Sedum sexangulare L. C.

Locally established, seemingly naturalized, mat-forming at several places on the Biological Station grounds (Thieret 48960 in 1976, MICH, UMBS). Leaves in six vertical ranks (not spiraled), shaped like slightly compressed pork sausages.

Penthorum sedoides L. C.

Old reports were rejected (1956, p. 60) in the absence of any specimens, but with the implied prediction that the species might indeed occur in the region. Piehl (1964, p. 42) cited his material (6083 in 1960, MICH, UMBS) from a muddy streamside near Mullett Lake (sec. 8, T36N, R1W); some miles away, ditch stonecrop is frequent in a wet ditch near the north end of Mullett Lake, SE¼ sec. 24, T37N, R2W (Voss 13684 in 1971, MICH, UMBS, EGV; 14504 in 1974, LKHD, MCT-F).

Ribes odoratum Wendl. f. E.

A currant apparently spreading in grassy waste land at site of an old collapsed dwelling near SW corner sec. 24, Pleasantview Tp., ca. 4½ mi. W of Brutus (Voss 14855 in 1976, MICH, UMBS, MSC, EGV). The mature fruit is black and tasty; younger fruits retain a long calyx tube which helps to identify the material. The Gates and Ehlers report (1925) was rejected earlier (1956, p. 61) because it was clearly based on cultivated plants and furthermore was unsupported by specimens.

[*Crataegus faxonii* Sarg.]

The collection reported as this species (1957a, p. 22) was subsequently re-examined by the late E. J. Palmer and annotated by him in 1958 as *C. ?chrysocarpa.* Since no other material referred to *C. faxonii* is known from the state, it seems best to be skeptical of this specimen.

[*Crataegus lucorum* Sarg.]

Through oversight, this was not listed in 1956 to be rejected (although mentioned on p. 61 under *C. boyntonii*). However, the material reported as *C. lucorum* by Gates and Ehlers was referred to *C. dodgei* in the companion paper (1957a, p. 21).

Crataegus ?suborbiculata Sarg. E.

A collection from the edge of a long-abandoned field by woods near French Lake, N½ sec. 23, Wawatam Tp. (Voss 3288 in 1956, MICH, UMBS, BLH, EGV) was referred to this species with a question-mark by Palmer in 1957, with the notation, "Leaves smaller and relatively narrower than type." It is reported here for the record. *C. suborbiculata* is described as having 20 stamens and the styles normally 5; the specimens in question have 10 stamens and 3 styles. I cannot associate the material with any other Michigan species, however; it confirms the unsavory reputation of the genus *Crataegus.*

Rubus setosus Bigelow E.

Swamp near west side of French Lake (Pringle 61 in 1963, UMBS). This is one of Gleason's "collective species" not previously reported from the region; Pringle (in litt., 1977) suggests that in a less extreme treatment the collection is presumably *R. wheeleri* (Bailey) Bailey (sensu Davis, Fuller, & Davis, Castanea 33: 61-62. 1968).

Caragana arborescens Lam. E.

The pea-tree is a locally common tall shrub, well established and fruiting in *Abies-Populus* woods with no sign of former habitation, E of Paige Creek, ca. 1 mi. E of Ramona (Voss 14063 in 1972, with J. Tanton, MICH, UMBS, MSC, EGV); fruiting in hardwood forest, sec. 17, T36N, R5W [Pleasantview Tp., ca. 6 mi. N of my site] (Hoffman & Poltorak in 1954, MSC). The only other Michigan collection I have seen is from hemlock-hardwoods at the Huron Mountain Club, Marquette Co. (Bingham in 1942, BLH; reported by Wells & Thompson, Occas. Pap. Huron Mt. Wildl. Found. 3: 46 [1976]–under Cruciferae). Not in the manuals for this region and seldom reported outside of cultivation, although there are recent records of the species persisting and perhaps spreading in North Dakota (Stevens, Rhodora 63: 43. 1961; 74: 392. 1972), South Dakota (Van Bruggen, Vasc. Pl. S. D., p. 281. 1976), and the prairie provinces of Canada (Boivin, Phytologia 15: 374. 1967; see also Nat. Canad. 93: 389. 1966–listing also Quebec). The map of the "cultivated range" of *C. arborescens* by Welsh (Iowa St. Jour. Sci. 35: 187. 1960) has no records in Michigan, and the accompanying text makes no reference to establishment of this species anywhere.

Lespedeza capitata Michaux C.

On the distribution map for this species by Clewell (Rhodora 68: 375. 1966) a single dot in the north half of the Lower Peninsula appeared to be in Cheboygan County. Correspondence elicited the information that there is a collection (not seen by me) in the herbarium of Iowa State University collected in 1924 at "State Park, Indian R., Mich." by Wiggins and Roupe. The species was surely a casual waif so far north and has not been seen again in the region.

Phaseolus vulgaris L. C.

The ordinary green bean is seldom thought to be established, but it was so widespread throughout waste ground at the Aloha Township dump, sec. 14, Aloha Tp., ca. 10 mi. SE of Cheboygan, that it seemed to warrant collection (Voss 14054 in 1972, with P. Raven, MICH, UMBS, EGV).

Vicia tetrasperma (L.) Moench C.

Roadside by wet ditch near culvert, Hebron Swamp (Clover & class in 1964, MICH, UMBS); long-abandoned golf-course ca. 1.5 mi. S of Mackinaw City (K. G. Voss in 1971, MICH, UMBS, EGV). Also found in neighboring Presque Isle Co.: limy, rocky area ca. 4 mi. S of Presque Isle lighthouse (Clover in 1961, UMBS).

Wisteria sinensis (Sims) Sweet E.

A woody vine climbing trees to a height of at least 25-30 feet, thickets along old road in mixed woods, with old plants of cultivated *Spiraea, Malus,* etc., near shore of Lake Michigan, sec. 5, West Traverse Tp., ca. 4 mi. NW of Harbor Springs (Voss 14860 in 1976, with J. Tanton, MICH, UMBS, EGV). Evidently the first report of wisteria "going wild" in Michigan.

Erodium cicutarium (L.) L'Hér. E.

Uncommon with other weeds in cultivated field, S edge SE¼ sec. 10, West Traverse Tp., ca. 1 mi. W of Harbor Springs (Voss 12858 in 1969, MICH, UMBS, EGV). The species was on the Fallass and Swift manuscript list as rare in waste places at Bay View, but specimens did not support this record.

Rhamnus cathartica L. E.

West bank of Tannery Creek, north of railroad tracks, sec. 28, T35N, R5W (Tanton in 1967, MICH, UMBS, MSC).

Rhamnus frangula L. E.

Two shrubs surrounded by many young plants in low wet area, sec. 5, T34N, R5W, Petoskey (Tanton in 1967, MICH, UMBS); occasional shrub in disturbed area of coniferous swamp, SE¼ sec. 34, Center Tp., ca. 6 mi. W of Pellston (Voss 12867 in 1969, MICH, UMBS, EGV); local shrub at edge of swampy mixed woods, SW corner sec. 35, Center Tp., ca. 5½ mi. W of Pellston (Voss 14502 in 1974, MICH, UMBS, MSC, BLH, EGV). The alder buckthorn, already a pest in southern Michigan, appears to be establishing itself northward. It was collected near the lighthouse on Round Island (next to Mackinac Island) in 1942 (Bingham, BLH); the only other northern Michigan records are from Osceola and Delta counties.

Malva alcea L. E.

Robinson Road beyond State Road on way to Lake Shore Drive (Clover in 1962, UMBS); locally frequent weed at Middle Village (Voss 12760 in 1968, MICH, UMBS, EGV).

[*Viola papilionacea* Pursh]

Viola affinis Le Conte C.

The material previously cited (1956, p. 64) to support retaining *V. papilionacea* on the list was redetermined by Norman Russell in 1970 as *V. affinis,* which thus replaces the former.

Oenothera pilosella Raf. C.

Dry roadside on north side of Moloney [sic] Lake, T38N sec. 11 (Clover in 1958, UMBS). The label is a printed form for Presque Isle County but must have been used in error as no part of that county extends into T38N, while Malone Lake is in sec. 11, T38N, R3W, in Cheboygan County.

Oenothera rhombipetala Torrey & Gray E.

North of Alanson (Clover in 1964, UMBS). Doubtless adventive this far north.

Cryptotaenia canadensis (L.) DC. E.

Ca. ½ mile on Division Rd. off Lake Shore Drive above and near Grove Basket Shop (Clover [in 1962?], UMBS).

Torilis japonica (Houtt.) DC. E.

Locally common at edge of an old orchard near center N edge sec. 25, Pleasantview Tp., ca. 4 mi. W of Brutus (Voss 14854 in 1976, MICH, UMBS, MSC, BLH, LKHD, EGV). Also seen around ruins of an old foundation near SW corner sec. 24 and abundant at ruins near center E edge sec. 26, where first found in 1975 by Pringle and Thieret (1600, MICH), noted by them as "abundant in fields." Evidently widespread in this township. Although not previously reported from the state, this species seems well established, as there are several collections from Ingham, Clinton, Eaton, and Washtenaw counties (MSC, MICH).

Moneses uniflora (L.) Gray, "double" form C.

A single double-flowered plant was found with occasional normal (or 4-petaled) ones by Peter Harley in a strip of cedar swamp near Grass Bay ca. 5 mi. E of Cheboygan, July 8, 1976 (Voss 14843, MICH). The flower bore no stamens, but had 10 extra white "petals," 3 of the inner ones with traces of non-functional anthers about two-thirds of the distance from the base to the apex, on the adaxial surface. All of the petals were slightly crisped-margined.

Centaurium minus Moench [*C. umbellatum* Gilib., nom. invalid.] C.

Locally frequent in damp waste ground along highway (M-27) ca. 1 mi. N of Indian River (Voss 13673 in 1971, MICH, UMBS, MSC, EGV). Well established at this site, which is also the only extant location known for *Dipsacus* in the region. Previously reported for the state from Mason Co. (1957b, p. 94).

Solanum sarrachoides Sendtner C.

Weed in flower bed in park at Western Ave. and Court St., Cheboygan. (Thieret 48818 in 1975, UMBS, KNK). This little South American weed of gardens, railroads, and waste places seems not to have been previously reported from Michigan; indeed, there are few specific records for North America although it occurs sporadically from coast to coast.

Mimulus moschatus Douglas C.

Black mud in drainage ditch below railroad, junction of Wing Rd. and railroad at NW corner of Mullett Lake (C. M. White 223 in 1964, MICH). The only Lower Peninsula record for this species, which is often considered a western disjunct in the Great Lakes region—if native here.

Veronica verna L. E. C.

Locally common with *V. arvensis*, gravelly roadside and driveway, 510 Lakeside Dr., Mackinaw City (Voss 11041 in 1963, MICH, UMBS, EGV).—Locally common, gravelly-sandy waste ground beside drive to old lighthouse, Mackinaw City (Voss 11042 in 1963, MICH, UMBS, MSC, BLH, GH). This species is distinguished from the common *V. arvensis* in having the upper and median leaves pinnatifid and the style slightly shorter. Not previously reported from Michigan; the only other material from the state I have seen is from Isle Royale (V. Bailey 5543 in 1959, MICH); West Bluff in Keweenaw Co. (Voss 11875 in 1965, MICH); a roadside table parking area on M-94 in Schoolcraft Co. (Henson 180 in 1970, MICH); and Aral pine plains in Benzie Co. (Thompson LB-2316 in 1976, BLH).

Asperula odorata L. E.

A large colony well established in cedar thicket near shore of Little Traverse Bay ca. 3½ mi. E of Harbor Springs (Voss 12875 in 1969, MICH, UMBS, EGV). Evidently the first report of sweet woodruff as an escape in Michigan.

Galium aparine L. E.

Locally abundant along abandoned trail road in rich beech-maple woods, sec. 10, Wawatam Tp., ca. 2 mi. W of Mackinaw City (Voss 12478 in 1967, MICH, UMBS, BLH, EGV). First noted 10 years ago, in a woods familiar to me for the preceding 20 years; now well established. The species has possibly been spreading north in recent years, especially in somewhat disturbed areas of rich woods, although not considered aggressive in North America (see Moore, Canad. Jour. Bot. 53: 878. 1975). Except for an old Farwell collection from Keweenaw County, the only material from north of the latitude of Saginaw Bay has been collected since 1940; rough bedstraw is now known from at least 12 northern counties.

Galium brevipes Fern. & Wieg. E. C.

Locally common, low spot in moist coniferous woods along East Ridge Trail, Wilderness State Park (Voss 9700 in 1960, MICH, EGV); local in gravelly beach meadow near W outlet of French Creek, sec. 28, Wawatam Tp., ca. 4 mi. SW of Mackinaw City (Voss 11360 in 1963, MICH, UMBS, EGV); dried bottom of Dingman Marsh Flooding (drawn-down this year) near dam, NW¼ sec. 4, T38N, R3W, ca. 5 mi. SE of Mackinaw City (Voss 14901A in 1976, MICH).—Banks of Nigger Creek near Topinabee (Ehlers 5603 in 1934, MICH); occasional, edge of Myrica at mucky border of Mud Lake ("Blanchard Bog"), sec. 21, Hebron Tp. (Voss 11714 in 1964, MICH, UMBS). There is a Presque Isle County collection in UMBS from east of Grand Lake (Clover in 1961), and a Delta County collection in MICH from Summer Island (Tessene et al. 65 in 1968); a Beaver Island collection is in CMC (S. Swan BI64-20 in 1964). Additional collections doubtless still masquerade in herbaria under *G. tinctorium* and *G. trifidum*. *G. brevipes* differs in its small flowers (ca. 1 mm wide or less) solitary or in 2's on smooth and short (to 5 mm) pedicels. The distinctions are carefully pointed out by Urban and Iltis (Trans. Wis. Acad. 46: 101-103. 1957), although difficulty must still be admitted in recognizing *G. brevipes*. A map published by Iltis (Rhodora 59: 41. 1957) shows the species in Cheboygan and Genesee counties. It is also recognized by Puff (Canad. Jour. Bot. 54: 1917-1918. 1976), whose map adds some Upper Peninsula localities but on too small a scale to offer any kind of details.

Galium palustre L. E.

A small colony in springy area at edge of thicket, shore of Little Traverse Bay ca. 3½ mi. E of Harbor Springs (Voss 12491 in 1967, MICH, UMBS, EGV).

Triosteum aurantiacum Bickn. C.

Edge of woods of red and white pine, bigtooth and quaking aspen, sec. 31, Mentor Tp., ca. 6 mi. NW of Wolverine (Voss 14858 in 1976, MICH, UMBS, MSC, EGV). A single plant noted, with crown of 25 fruiting stems (of which 4 were collected for specimens). The rejected old report (see Voss 1956, p. 67) of *T. perfoliatum* from near Black Lake probably referred to this species, but in the absence of specimens to support it one cannot be sure.

Dipsacus fullonum L. [*D. sylvestris* Hudson] C.

Scarce (one small clump) on grassy shoulder of highway (U.S. 23) ca. 3.5 mi. NW of center of Cheboygan (Voss 7948 in 1958, MICH, UMBS, EGV); locally established in waste ground on W side of highway (M-27) near center E edge sec. 13, Tuscarora Tp., ca. 1 mi. N of center of town of Indian River (Clover in 1963, UMBS; Voss 11366 in 1963, MICH, EGV). The Indian River colony continues to thrive, as does *Centaurium minus* at the same site; the colony of teasel between Cheboygan and Mackinaw City seems to have died out.

Ambrosia ×*heleneae* Rouleau C.

The ragweed hybrid *Ambrosia artemisiifolia* × *A. trifida* was collected on a street in east Cheboygan (Ehlers 5346 in 1933, UMBS); the collection was cited by Wagner in his discussion of this hybrid (Rhodora 60: 311. 1958) and its determination confirmed by W. W. Payne in 1964.

Aster novae-angliae L. E. C.

Occasional in old field or meadow between highway (U.S. 31) and Crooked Lake, SW¼ sec. 18, Littlefield Tp., ca. 1 mi. W of Oden (Voss 12514 in 1967, MICH, UMBS, EGV); fairly common throughout low wet area, sec. 5, T34N, R5W, in Petoskey (Tanton in 1967, MICH, UMBS).–One patch at edge of mixed woods near center S edge sec. 6, T33N, R1W, ca. 6 mi. E of Wolverine (Voss 3297 in 1956, MICH, UMBS, SMU, EGV; det. confirmed by L. H. Shinners in 1959). The Cheboygan County collection was made October 14, 1956, and this aster was thus the first species to be restored to the list after having been rejected (1956, p. 68) for lack of any correctly identified material. New England aster is not known from the Upper Peninsula.

Aster umbellatus Mill. [incl. *A. pubentior* Cronq.] C.

Uncommon, edge of swamp forest near W edge NE¼ sec. 29, T33N, R1E, ca. 9 mi. SSE of Tower (Voss 11713 in 1964, MICH). Plants (not always flowering) were noted here a few subsequent years but have not been sought recently. The flat-topped aster is common many places in the Upper Peninsula and in Ontario north of Lake Superior, and it is surprising to find the species so rare and local in the northern Lower Peninsula. It, too, had been rejected (1956, p. 68) in the absence of specimens to support early reports.

Bellis perennis L. E. C.

Locally common in grassy area around Veling cottage ca. ½ mi. NE of Cross Village (Voss 12655 in 1968, MICH, UMBS, MSC, EGV).–Local, lawn of cottage at N end of Burt Lake (S. Freed in 1969, UMBS; Voss 12863 in 1969, UMBS). English daisy is also reported to be common on the Mullett Lake golf course; it is surprising that this lawn weed has not previously been collected in the region.

Bidens connatus Willd. C.

South side of Mud Lake Bog (Gates 12515 in 1920, UMBS); shore of Burt Lake near Carp Creek (Gleason in 1912, UMBS). Both collections were determined as *B. connatus* var. *petiolatus*[5] by E. E. Sherff in 1957; the species was prematurely deleted from the list (1956, p. 69).

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[5] The name *Bidens* has traditionally been treated as feminine, especially in America, despite a classical gender of masculine, with the defense that the word may be considered an adjective agreeing with "herba" or "planta" understood. However, the International Code of Botanical Nomenclature clearly states (Art. 20.1) that all generic names are treated as substantives, and that classical gender should be followed regardless of the usage of authors (Rec. 75A).

Cirsium discolor (Willd.) Sprengel E.

Corner of State Rd. and Middle Village Rd. (D. Eliot in 1965, UMBS).

Cirsium flodmanii (Rydb.) Arthur C.

Roadside near Mud Lake (Ehlers 3484 in 1926, UMBS, MICH; det. G. Ownbey in 1959). This is the material reported by Gates and Ehlers (1928) as *C. undulatum* from Cheboygan County. (The Emmet County material of *C. undulatum* is in UMBS [Gleason in 1917] and was confirmed as that species by L. H. Shinners in 1952—at which time the duplicate sheet of Ehlers 3484 [ex. herb. R. R. Dreisbach] had not yet been placed in UMBS.)

Cirsium palustre (L.) Scop. E. C.

Damp open area in Wilderness State Park (L. Oakley in 1962, UMBS); scarce in moist thicket near trail road between Waugoshance Pt. road and Sturgeon Bay cabin, Wilderness State Park, near center E edge sec. 30, T39N, R5W (Voss 11333 in 1963, MICH).—Scarce (a single plant seen and collected), bog forest at E edge sec. 18, Hebron Tp., ca. 7 mi. S of Mackinaw City (Voss 8857 in 1959, MICH); small colonies occasional in ditch along dense thickets at W edge secs. 29 & 32, Mackinaw Tp., ca. 3-4 mi. S of Mackinaw City (reported as having been here for several years) (Voss 13875 in 1972, UMBS). This unpleasant thistle has now spread throughout the Upper Peninsula, where it was first discovered in the state by Fernald in 1934 (see Voss, 1957b, p. 97); and it has crossed to the mainland of the Lower Peninsula. It seems not to be spreading as aggressively here as farther north, but small colonies persist on Waugoshance Point and along the Stimpson Road in Mackinaw Tp. It is also on Bois Blanc Island (Mackinac Co.) (Voss 14352 in 1973, MICH) and Garden Island (Charlevoix Co.) (Voss 4853 in 1957, MICH).

Echinops sphaerocephalus L. E.

Filled ground on shore of Little Traverse Bay in Harbor Springs, immediately west of the Irish Marina (Tanton in 1967, MICH, UMBS). A colony of about 20 plants of the globe-thistle was reported here; and the collector reports another colony in the SE¼ sec. 3, T34N, R5W.

Helenium flexuosum Raf. [*H. nudiflorum* Nutt.] E.

In marsh ground along highway where Carp Lake River crosses Wilderness Park Road (C. W. Bazuin 3794 in 1941, MICH); the label says "Charlevoix Co." but a duplicate of this number in BLH is labeled "Emmet Co." and says "Carp Lake River, just west of Carp Lake, wet meadow." The only previous Michigan record is from Kalamazoo Co. (Rhodora 38: 367. 1936; Hanes, Fl. Kalamazoo Co., p. 260. 1947); a sheet of this collection (Becker in 1935, MICH) was confirmed by Rock and is presumably the basis for the Michigan dot on his map (Rhodora 59: 139. 1957). I have seen one additional Michigan specimen, from Delta County, where it was said to be frequent in dry sandy soil, sec. 26, T43N, R19W (Marshall 908 in 1949, MSC).

Helianthus tuberosus L. E.

The Jerusalem artichoke was tentatively excluded from the regional list (1956, p. 69) since the only material was sterile and not certainly determinable. The species may definitely be restored on the basis of excellent specimens from Brubaker Rd., NE¼ sec. 15 and NW¼ sec. 14, T34N, R5W (Bear Creek Tp.) (Tanton in 1967, MICH, UMBS); also reported by the collector as seen behind Ottawa School on Kalamazoo St. in Petoskey.

Lactuca muralis (L.) Gaertner C.

This species has been known in Michigan from Mackinac Island and nowhere else (Piehl, 1964, p. 43). In 1942 it was found, however, on neighboring Round Island (Bingham, BLH), and in 1968 I collected it just west in the Straits of Mackinac on St. Helena Island (Voss 12833, MICH, UMBS, EGV), where I noted in 1976 that it still occurred. The collection recently discovered in UMBS is thus the fourth locality (and second county) known for Michigan. The label reads "Along mouth of upper Maple River C. J. Reddington July 31, 1963." Someone other than the collector himself evidently typed the label, since his middle initial is wrong and his name is misspelled. Charles B. Redington was enrolled in my aquatic plant class in the summer of 1963 and also in Dr.

Clover's plant taxonomy class, for which he would have had to present a collection of a certain family—evidently the Compositae. On July 31, however, he was on an all-day trip with the aquatics class down the Upper Black River to its mouth at Black Lake, in Cheboygan County. Since no branch of the Maple River is known as the "upper Maple River" and the collector would hardly have had an opportunity to be anywhere on the Maple River system the day of the collection, I am assuming that the locality should be the Upper Black River (where the plant obviously did not register with me!). A printed label form for Emmet County was used, but such errors are common among student collections of the era. (Another interpretation of the label would be that that the date is wrong, but the Maple River and Emmet County designations are correct.)

Tragopogon hybrids

All three species of goatsbeard (*T. dubius, T. porrifolius,* and *T. pratensis*) grow commonly on the west and northwest side of Cheboygan, especially along the railroad tracks from Lincoln St. to State St. and west along State. All three hybrids occur here, and were used regularly for class demonstrations 1967-1974; although I have photographs, unfortunately documenting specimens have not been made except for the commonest of the hybrids, *T. porrifolius* × *T. pratensis,* previously reported (1957a, p. 34). A photograph of this hybrid from the Cheboygan railroad station area appeared in Rickett's *Wild Flowers of the United States* I: 505 (1966), erroneously captioned as simply *T. porrifolius* in the first printing, although the curly leaf tips, swollen peduncles, bi-colored ligules, and intermediate ligule color clearly indicate the parentage (as stated on the original slide).

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CROWN POSITION AND HETEROPHYLLY IN WHITE OAK

Richard R. Braham
School of Forest Resources
North Carolina State University
Box 5488, Raleigh, North Carolina 27607

The oaks (*Quercus*) are generally regarded as taxonomically difficult. Their leaves are often highly variable in size and shape, and this feature accounts for much of the difficulty. Hybridization between oak species is frequently cited as the cause of variability. While hybridization may increase variability, other factors may be involved. Studies in other genera show that within-tree heterophylly, the forming of differently shaped leaves caused partly by microenvironments, can be a source of variability. Heterophylly has been shown in such unrelated genera as *Parthenocissus, Ginkgo, Acer, Fraxinus,* and *Betula* (Critchfield, 1970a, b, 1971; Gill, 1971; Dancik & Barnes, 1975).

Heterophylly may also occur in oaks; oak trees often develop complexly branched crowns, and leaves in different positions in the crown occur in different microenvironments. Furthermore, since heterophylly contributes to the difficulty of both field identifications and detailed taxonomic investigations, establishing a standard position in the crown where the within-tree variability is minimized would make such work easier. Leaf collections used for comparative purposes could then be taken from this standard position.

The objectives of this study were to investigate some of the effects of crown position on heterophylly in open-grown oak trees and to establish a position in the crown where the variability in leaf morphology is minimized.

Three mature, open-grown white oaks, *Quercus alba,* were selected as study trees. The trees were located in an old fence row at The University of Michigan's Matthaei Botanical Gardens (Washtenaw Co., Township 2S, Range 6E, sect. 13). The trees were all similar in size, had a mean diameter breast height of 72 cm, a mean crown-spread of 9 m, and a mean height of 17 m. For sampling purposes the tree crown was divided into the north and south halves. In each half the crown was further divided vertically into thirds. In the bottom- and middle-thirds, two sampling positions were selected, one at the periphery of the crown (outer crown) and one in the interior (inner crown). In the upper-third, one sampling position was selected at the periphery of the crown. Only one position was used in the upper-third because of the difficulty of obtaining leaf samples at 14 to 17 m above the ground. At each sampling position four shoots, two terminal and two lateral, were collected. Five sampling positions on each of the north and south sides made a total of 10 positions.

Each leaf from each shoot was measured using the following characters: blade length, blade width, distance from the base to the widest part of the blade, the diameter of the blade which is undissected by sinuses (inside diameter), the length of the petiole, the depth of the smallest sinus, the depth of the largest sinus, the number of sinuses, the number of second-order veins, the amount of pubescence, and the numerical position of the leaf on the twig. Two other characters were recorded on each shoot: the length of the shoot and whether the shoot was originally in a terminal or lateral position on the branch in the crown (shoot position).

All leaves were assumed to be bilaterally symmetric, and to simplify the procedure only half of the leaf, the left-adaxial side, was measured. All measurements, made to the nearest millimeter, are similar to those made by Maze (1968), Ledig et al. (1969), and Baranski (1975) in their work with oaks.

The data were first analyzed by using a univariate model, the analysis of variance. To test for within-tree variation, the leaves were divided into 10 groups, corresponding to the 10 sampling positions in the crown. Hypothesis tests were made to determine whether there were significant differences in character means related to crown position. Scheffé multiple comparisons were used to determine exactly where differences occurred, if any. The variance of each character was noted for each of the 10 crown positions to establish a position where the variance was minimized.

To test for within-shoot variation the leaves were divided into 16 groups, corresponding to whether the leaves came from terminal or lateral shoots and their numerical position on the shoot. The first leaf below the terminal bud was numbered leaf one. Hypothesis tests and Scheffé multiple comparisons were used to test for differences, and the variances of each leaf character were again recorded. From an analysis of the residuals, it appeared as if the underlying assumptions of the analysis of variance model had not been violated.

The data were further analyzed by using a multivariate model, the canonical correlation. Canonical correlation analyzes the correlations between two groups of characters. The first group was composed of characters relating to leaf morphology: blade length, blade width, distance from the base to the widest part of the blade, inside diameter, petiole length, depth of the smallest sinus, depth of the largest sinus, number of sinuses, number of veins, and amount of pubescence. The second group was composed of characters relating to the shoot: numerical position of the leaf on the shoot, length of the shoot, and shoot position.

Univariate Analysis

A total of 606 leaves were collected and measured. Leaves collected from the periphery of the middle-third of the crown, north side, generally had the largest character means (Table 1). Leaves collected from the north side of the crown also had mostly larger means when compared with leaves from the

TABLE 1. Comparison of white oak leaves collected from 10 different positions in the crowns of three trees. (Mean values of selected characters, all length measurements in cm.) Variables: BL = Blade length, BW = Blade width, DBW = Distance from the base to the widest part of the blade, ID = Inside diameter, PL = Petiole length, DSS = Depth of the smallest sinus, DLS = Depth of the largest sinus, NS = Number of sinuses. An asterisk * indicates a mean different from other asterisked means, at $P < 0.01$.

			Variable							
Crown Position			BL	BW	DBW	ID	PL	DSS	DLS	NS
North Side	Outer	Upper	10.8	6.9	6.9	1.6	1.6	0.7	2.4	3.6
		Middle	12.7	8.4*	7.8	2.1*	1.8	0.8	3.1	3.7
		Lower	11.7	6.5	7.2	1.4	2.1	0.8	2.4	3.0
	Inner	Middle	11.9	7.8	7.4	2.0	1.6	0.6	2.9	3.7
		Lower	12.1	6.5	7.6	1.5	2.0	0.7	2.2	3.2
South Side	Outer	Upper	11.9	7.2	7.4	1.4	2.1	0.9	2.7	3.0
		Middle	10.8	5.6*	6.7	1.2*	1.8	0.5	2.0	3.4
		Lower	11.6	6.3	7.0	1.7	1.9	0.1	2.1	3.1
	Inner	Middle	11.9	7.1	7.6	1.6	1.9	0.7	2.6	3.1
		Lower	11.7	6.1	7.0	1.8	2.0	0.7	1.8	3.1

south side, but only two statistically significant differences among character means related to crown position were found. Blade width of leaves from the periphery of the middle crown, north side, was significantly larger than blade width from the similar position on the south side (8.4 cm vs. 5.6 cm; $P < 0.01$), as also was inside diameter (2.1 cm vs. 1.2 cm; $P < 0.01$). But blade width and inside diameter means for these two positions were not significantly different from those of the other eight crown positions.

The significant differences in leaf characters related to crown position were confined to the middle-third of the crown. Leaves from the upper- and lower-thirds, north and south sides, were not significantly different in any characteristic. In forest-grown trees we typically think of leaves in the upper crown as being morphologically different from leaves in the lower crown, owing partly to differences in incident sunlight (Daubenmire, 1974). This pattern was not observed in the open-grown trees I sampled. The light regime of open-grown trees is undoubtedly quite different from forest-grown trees owing to the lack of surrounding vegetation. Thus much of the crown of open-grown trees probably receives similar amounts of sunlight. Under such conditions leaves from the upper crown may not be morphologically different from leaves of the lower crown.

Leaves from the periphery of the middle crown, north side, were significantly wider than leaves in a similar position on the south side. Leaves in the former position are probably subjected to the least amount of direct sunlight because of shading from the surrounding crown. As mentioned above, shading of leaves may result in morphologically distinct leaves, and this phenomenon likely accounts for the observed differences.

When the variances of the leaf characters for each of the 10 crown positions were compared, without regard to whether the leaves came from terminal or lateral shoots, no single position was consistently least variable for all characters. Some patterns were evident, however. The inner crown, south side, was the most consistent in leaf morphology, particularly with regard to leaf size. This position was least variable for the characters of leaf length, leaf width, distance from the base to the widest part of the blade, and depth of the largest sinus. A different position of the crown was least variable for each of the remaining characters. In all but three characters (inside diameter, number of sinuses, and number of veins) the scuth side of the crown was less variable than the north side.

Collections from open-grown trees to be used for comparative purposes are best collected from the south side, since the south side showed a more consistent leaf morphology. In particular, the lower, inner crown of the south side is the best position for collecting when comparisons based on leaf size are to be made. The present study did not calculate variances related to both crown and shoot position. Had this calculation been made, the collection position suggested above may have proved inferior to another position. The difference in leaf morphology between terminal and lateral shoots for outer crown positions was more pronounced than inner crown positions, and thus all leaves from the outer crown considered together had a higher variance. Had I further stratified the samples, by both crown and shoot position, the results may have been different. Variances related to both crown and shoot position should be calculated in future studies.

For within-shoot variation, Scheffé's multiple comparison showed that all leaves tended to group into one of three categories, which I termed alpha, beta, and delta (Fig. 1). Leaves produced at the tips of terminal shoots,

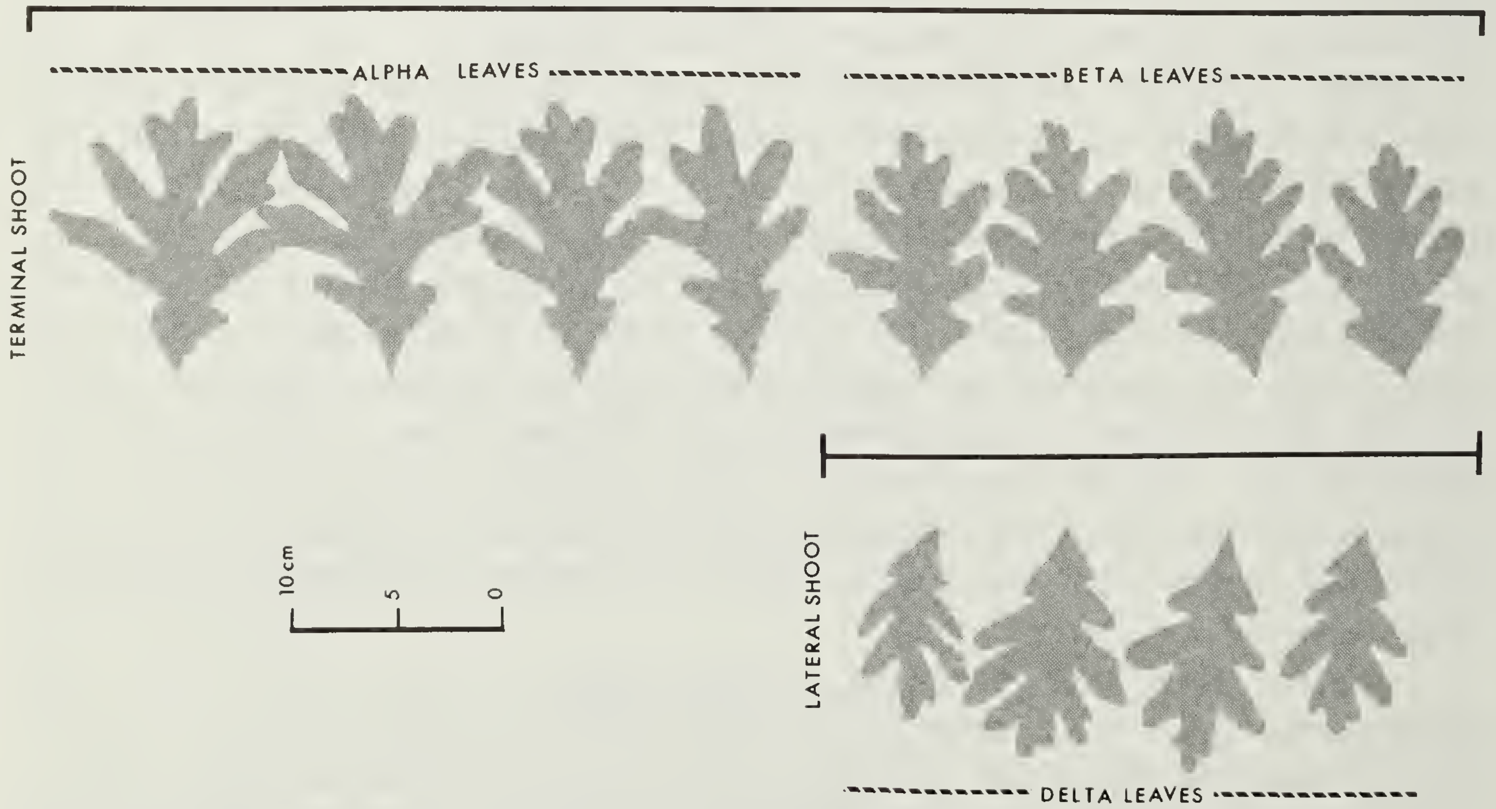

Fig. 1. Leaf types produced in white oak; alpha and beta leaves from terminal shoots and delta leaves from lateral shoots. Leaves not connected by a solid horizontal line are significantly different at $P < 0.001$.

generally the first four leaves, were all statistically the same; I called these alpha leaves. Alpha leaves were significantly larger than all leaves on lateral shoots in blade length, blade width, distance from the base to the widest part of the blade, and petiole length ($P < 0.001$, Table 2). The remaining lower leaves on terminal shoots, beta leaves, were not significantly different from either alpha leaves or leaves produced on lateral shoots. Delta leaves, all leaves produced on lateral shoots, were significantly different ($P < 0.001$) from alpha leaves, but not beta leaves.

Within-shoot variation of leaf morphology seems to follow a pattern based principally on leaf size, numerical position of the leaf on the shoot, and shoot position. This heterophylly, however, is not as pronounced as found in black cottonwood, *Populus trichocarpa* (Critchfield, 1960), and trembling aspen, *Populus tremuloides* (Barnes, 1969).

The fifth leaf on terminal shoots was found to be the least variable in morphology, particularly with regard to leaf size. It was least variable for the characters of leaf length, leaf width, distance from the base to the widest part of the blade, and the depth of the largest sinus. The first leaf on terminal shoots was the least variable for petiole length and the number of sinuses, but for each of the remaining characters a different leaf was least variable. On lateral shoots the second leaf was least variable for five characters: leaf length, distance from the base to the widest part of the blade, number of sinuses, depth of the smallest sinus, and number of veins. The fourth leaf was least variable for two characters: leaf length and petiole length.

TABLE 2. Comparison of white oak leaves collected from terminal and lateral shoots. (Mean values of selected characters, based on a sample of 606 leaves; all measurements in cm.) Variables: BL = Blade length, BW = Blade width, DBW = Distance from the base to the widest part of the blade, ID = Inside diameter, PL = Petiole length, DSS = Depth of the smallest sinus, DLS = Depth of the largest sinus. Means not connected by a vertical line are significantly different at $P < 0.001$.

		Variables							
	Leaf No.	n	BL	BW	DBW	ID	PL	DSS	DLS
Terminal Shoots	1	60	12.3	6.8	8.0	2.0	1.8	0.6	2.3
	2	60	12.2	7.4	7.8	2.0	1.8	0.6	2.6
	3	60	12.0	7.4	7.8	2.0	1.7	0.6	2.5
	4	59	12.5	8.0	8.0	2.1	1.8	0.7	2.8
	5	53	11.2	7.2	7.0	1.9	1.7	0.7	2.5
	6	42	11.2	6.7	7.2	1.8	1.8	0.7	2.3
	7	29	9.8	6.0	6.1	1.9	1.6	0.6	2.1
	8	9	10.2	6.3	6.7	1.6	1.7	0.8	2.2
	9	4	11.0	6.6	7.4	1.8	2.0	0.7	2.2
	10	4	9.2	5.6	6.3	1.5	1.8	0.6	1.6
Lateral Shoots	1	60	9.3	5.1	6.0	1.9	1.3	0.5	1.6
	2	60	9.5	5.6	6.2	2.0	1.4	0.5	1.8
	3	52	9.2	5.2	5.9	1.8	1.2	0.5	1.6
	4	35	9.1	5.2	6.0	1.8	1.3	0.5	1.7
	5	15	7.5	4.2	4.2	1.5	1.1	0.4	1.3
	6	3	7.9	4.3	5.5	1.4	1.3	0.3	1.6

When sampling leaves, using the fifth leaf from the bud on terminal shoots and/or the second leaf on lateral shoots as standard collection positions would markedly reduce the variation of the sample related to within-shoot heterophylly.

Multivariate Analysis

To test whether the morphology of a leaf is correlated with its position on the shoot, the canonical correlation was used. There was a significant first correlation of 0.82 between the two groups ($P < 0.001$). Variables of the first group which were especially important in this correlation were blade length, blade width, number of veins, and amount of pubescence. In the second group the numerical position of the leaf on the shoot was important.

The canonical correlation shows that the size of a leaf is strongly influenced by the numerical position of the leaf on the shoot. This conclusion supports the results from the within-shoot variation study. Thus comparisons of leaves in taxonomic studies should be based on leaves collected from similar portions of the shoot. Such collecting will help minimize variation due to within-shoot heterophylly.

CONCLUSIONS

Oaks are notorious for their leaf variability which makes identification in the field difficult and makes detailed taxonomic studies even more troublesome. This study has shown that some of their non-genetic within-tree variability is related to the physical position of the leaf in the crown. By stratifying leaf samples and only comparing samples from similar areas of the crown and shoot, the non-genetic variability may be minimized, and taxonomic determinations and studies made easier.

Few differences were found between leaves collected from 10 different positions in the crowns of three open-grown white oaks. Leaf shape in open-grown trees is not as strongly affected by crown positions as has been reported for forest-grown trees. The leaves on the south side of the crown are less variable than leaves from the north side, particularly with regard to leaf size. Thus, leaves to be used for comparative purposes are best collected from the south side of the crown.

Variation within shoots follows a more distinct pattern of heterophylly than within crown. I termed the three major kinds of leaves formed within shoots, alpha, beta, and delta leaves. The kinds of within-shoot leaves vary in leaf size, numerical position on the shoot, and shoot position. The fifth leaf on terminal shoots and the second leaf on lateral shoots are the least variable in morphology. When sampling leaves, using the fifth leaf on terminal shoots or the second leaf on lateral shoots minimizes the variance of the sample related to within-shoot heterophylly. Multivariate analysis supports the above conclusions. Canonical correlation shows that the size of the leaf is strongly influenced by its position on the shoot.

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A PRAIRIE GROVE IN SOUTHWEST MICHIGAN

Michael Fleckenstein and Richard W. Pippen
Biology Department, Western Michigan University,
Kalamazoo, 49008

Before the settlement of southern Michigan, travelers from the east crossed forested land until they reached large open prairie lands in the southwestern portion of the state. Located in the center of one of these prairies was a 300-acre mixed hardwood forest described by James Fenimore Cooper (1848) as an "island of trees in a sea of grass." So distinctive was this grove that it became a landmark to travelers known as the Big Island (Hanes, 1944), hereafter referred to as the Island (Fig. 1). The Island, located in the south end of Kalamazoo County, at the southwest corner of section 18, Schoolcraft Township, is now a 24-acre woodlot. Most of the former acreage is occupied by the village of Schoolcraft.

Before settlement, the Island was completely encircled by Prairie Ronde (Michigan's largest prairie, now under cultivation). The prairie separated the Island from beech-maple woodlands. American Beech (*Fagus grandifolia*) does not presently occur in the Island woods, nor are there any *bona fide* records that it ever did. Vegetation maps, composites of early survey records, as well as the original land survey (Hodgman, no date), show beech-maple forest located immediately to the west of Prairie Ronde and oak-hickory immediately to the north and east (Kenoyer, 1929; Peters, 1969). The lack of

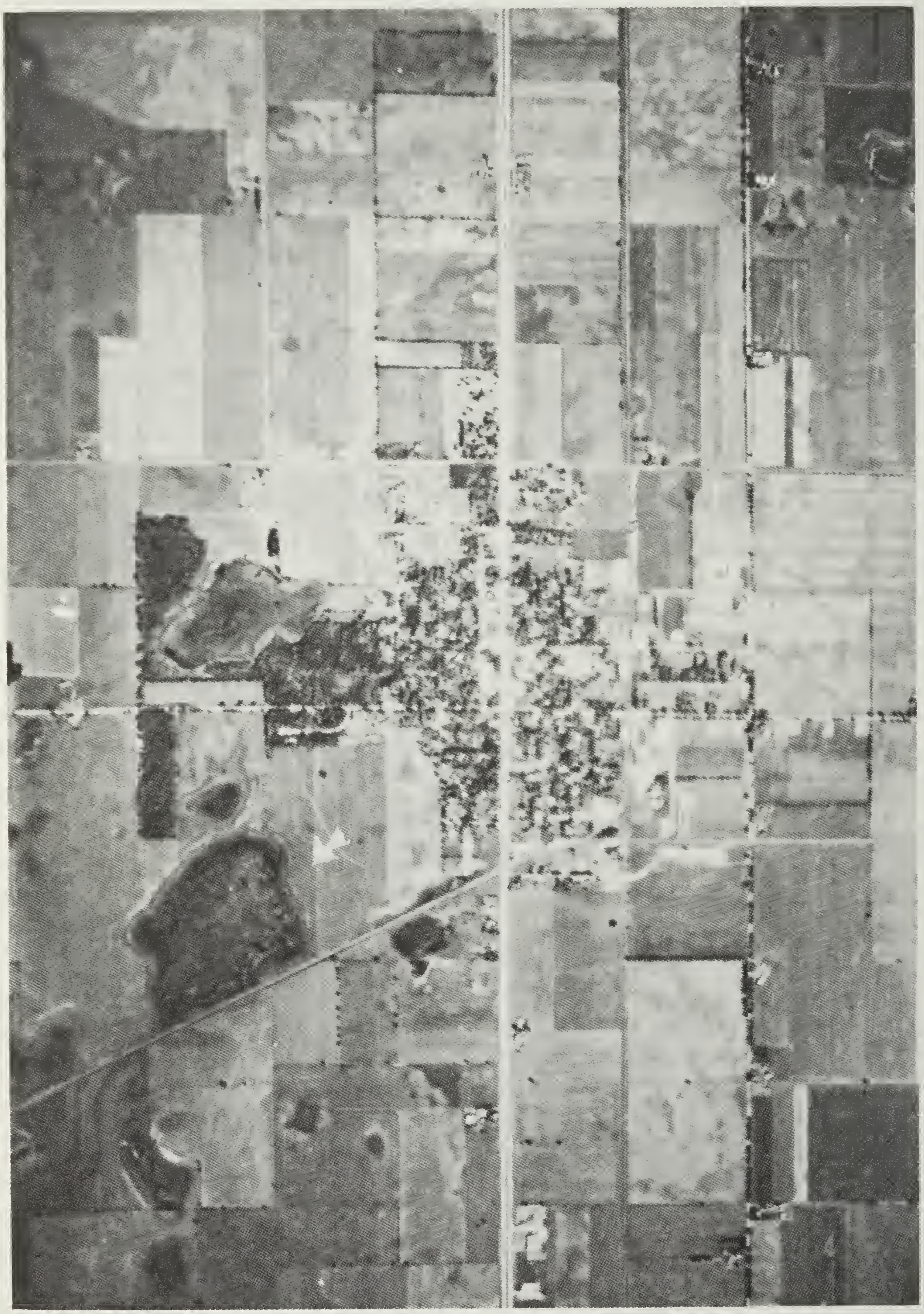

Fig. 1. Aerial photograph showing the Island to the left of the village of Schoolcraft encircled by historic Prairie Ronde. Note the ponds to the northwest and southwest of the Island. (Photograph from USDA Commodity Stabilization Service, 1967, BDW 3HH 113.)

vegetative similarity to these forests surrounding Prairie Ronde suggests that the Island was never connected to nearby woodlands.

This study shows that the plant association found at the Island, both historic and present, is more similar to the prairie groves of Illinois than to the surrounding beech-maple associations in southern Michigan.

The occurrence of small discontinuous patches of prairie vegetation was originally used to define the prairie peninsula which was considered to be an extention of the prairie eastward through parts of Illinois, Indiana, and Michigan (Transeau, 1935; Braun, 1950). Prairie groves may serve equally well in defining the peninsula and perhaps serve to strengthen its phytogeographic significance.

Forests in the vicinity of prairies were found predominantly on adjacent river bottomlands, but occasionally, throughout the prairie peninsula, wooded uplands were isolated on prairies and not adjacent to rivers. Little research has been conducted on such upland forests, although reference to their existence may be found in numerous works.

The occurrence of woodlands on prairies has not been well studied. While not treated in depth here, their development is important in understanding the character of the prairie groves of this study. The development of forest vegetation in the prairie peninsula area occurred soon after the last glacial retreat and probably during a late xerothermic period some 3500 years bp (Curtis, 1959). Oak migration was followed by beech-maple and maple-basswood associations as conditions became suitable. Pollen studies suggest that beech in its northwestward migration was filtered out by the prairie peninsula but not before it was established in southwest Michigan possibly by another route (Benninghoff, 1964). Woodlands may have extended across rolling uplands and ridges in Illinois, gaining a foothold on eroding sod (Gleason, 1909; Stout, 1946). They may have been cut off later by sweeping fires, protected in part by firebreaks leaving only isolated groves. Some authors, on the other hand, have felt that isolated oaks and elms gained a foothold on the open prairie through dissemination by animals and wind, respectively (Woodward, 1925). Wells (1965) described scarp woodlands of the eastern edge of the Great Plains as "relics of formerly more extensive woodlands" which survived the alluvial deposition of outwash from the Pleistocene glaciation.

Fires seem to be the major force that maintained the prairies and oak openings and pushed back the dense woodlands. Cessation of fires with the advent of cultivation allowed the dense oak growth to begin in the openings throughout the prairie peninsula (Curtis, 1959; Cottam, 1949). A certain amount of caution must be employed at this point. When settlers moved into Michigan the Island was already a mature forest. This was probably because ponds located in and around the Island created fire breaks similar to those described by Gleason (1909). Fire breaks plus higher relative humidity associated with the Michigan portion of the peninsula (Transeau, 1935) reduced the frequency of fires.

Comparisons of the vegetation of the Big Island were made with the prairie grove in Logan County, Illinois, in sections 7, 8, and 18, Elkhart

Township, hereafter referred to as Gillet Hill (Fig. 2), and with a beech-maple association at the Kalamazoo Nature Center, section 27, Cooper Township, Kalamazoo County, hereafter referred to as Cooper's Glen, to determine whether the Island has more affinity to prairie groves of Illinois or nearby beech-maple associations.

Selection of the two prairie-associated woodlands was based on their isolation in the prairie peninsula and the presence of a number of species shared in common. A comparison of the species composition of Gillet Hill with that of another isolated prairie grove in Illinois studied by Gleason (1909) showed that the vegetation of Gillet Hill is probably typical of the prairie grove associations of Illinois. Cooper's Glen was chosen because it represents a typical beech-maple association in southern Michigan (Zager & Pippen, 1977).

Each area was sampled by a random-quadrat technique. Selection of random quadrats was accomplished with a PDP-10 computer generation at Western Michigan University. A Brunton pocket transit and nylon rope marked at one-meter intervals were used to locate quadrats in the field. Quadrats one meter on a side were used to sample all herbaceous vegetation and tree seedlings less than one inch dbh. Quadrats 10 meters on a side were used for trees greater than one inch dbh. During the middle of April, 70 quadrats were counted for herbaceous data; 30 were counted for trees during late June. The same number was counted at Gillet Hill for each group during the latter part of April. Although the herbaceous data are not comparable, a data base was established for further study. The southwest slope was sampled at Gillet Hill while the east-southeast slope was assessed for species content.

Soil samples were taken at the Island and Gillet Hill to determine color and texture differences. Cooper's Glen data were obtained from a recent study by Zager & Pippen (1977). Voucher specimens from the Island were placed in the C. R. Hanes Herbarium at Western Michigan University.

DESCRIPTION OF THE ISLAND

The topography of the land immediately in and around the Island is that of low rolling hills. Three- to five-acre, water-filled depressions dot the landscape especially to the southwest of the Island. The highest point at the Island site is approximately 15-20 feet above the water surface and slopes toward the water approximately 10 feet every 215 feet. Consequently, the water table, especially during wet years, is relatively high, leading some to

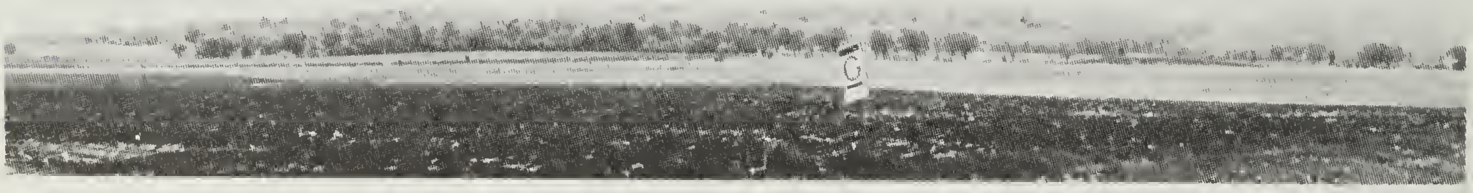

Fig. 2. Photograph of the west side of Gillet Hill. Note the abrupt rise in the landscape at the foreground and the length of the ridge.

misinterpret the Island as a swamp forest (Kenover, 1929). This interpretation was probably based on the presence of American Elm (*Ulmus americana*), Basswood (*Tilia americana*), and lone specimens of Sycamore (*Platanus occidentalis*) and Ohio Buckeye (*Aesculus glabra*). However, lowland-dominant Silver Maple (*Acer saccharinum*) and (less important) Green Ash (*Fraxinus pennsylvanica*) are not present.

The soil in the Prairie Ronde vicinity was reported to be glacial outwash (Kenoyer, 1929; Braun, 1950) but is more recently reported to be glacial till (Straw, personal communication). The drainage potential of till is greater than that of outwash and could partially explain the existence of prairie vegetation in this area. Soil samples from the Island indicate a four- to six-inch humus layer above a dark-brown and then yellow-gray loam characteristic of leached forest soils.

Maples (*Acer saccharum, A. nigrum,* and their hybrids), American Elm, Hackberry (*Celtis occidentalis*), and Basswood comprise the dominant trees of the Island (Table 1). Black Maple (*A. nigrum*) is more abundant in the west end of the Island shifting to Sugar Maple in the east. Hybrids of *A. saccharum* and *A. nigrum* occur throughout the transition zone. American Elm gives way to Slippery Elm (*Ulmus rubra*) toward the pond at the north edge of the Island. White Ash (*Fraxinus americana*), Blue Ash (*F. quadrangulata*), and Paw

TABLE 1. Comparison of the woody vegetation at the Island (a), Gillet Hill (b), and Cooper's Glen (c). Density (number per acre). Frequency (%).

	Density			Frequency			Relative Density		Relative Frequency		Abundance	
Species	a	b	c	a	b	c	a	b	a	b	a	b
Acer saccharum	173.2	44.6	48.8	94.9	56.7	70.0	25.4	9.7	16.6	20.7	4.5	1.9
Ulmus americana	130.7	284.0	1.6	79.5	90.0	4.0	19.2	53.7	13.9	32.9	4.1	6.8
Acer saccharum ×A. nigrum	94.7	2.4		87.2	6.7		13.9	.5	15.3	2.5	2.7	1.0
Celtis occidentalis	93.4	21.6		79.5	23.3		13.7	4.7	13.9	8.5	2.9	2.3
Tilia americana	58.3	5.3	5.6	43.6	3.3	14.0	8.5	1.1	7.6	1.2	3.3	4.0
Prunus serotina	44.5			51.3			6.5		9.0		2.2	
Asimina triloba	24.9	118.6		20.5	63.3		3.7	25.7	3.5	23.1	3.0	4.6
Acer nigrum	15.4	10.8		23.1	16.7		2.3	2.3	4.0	6.1	1.7	1.6
Carya ovata	15.5			25.6			2.3		4.5		1.5	
Morus rubra	9.3			20.5			1.4		3.6		1.1	
Juglans nigra	7.1	4.1		25.6	6.7		2.1	.9	4.5	2.5	1.4	1.5
Ostrya virginiana	5.2			10.3			.8		1.8		1.3	
Fraxinus quadrangulata	4.2			10.3			.6		1.8		1.0	
F. americana	4.2			7.7			.6		1.4		1.3	
Cercis canadensis		4.1			3.3			.9		1.2		3.0
Unknown sp.		2.4			3.3			.5		1.2		2.0

Paw (*Asimina triloba*), although not very abundant, also occur at the Island. Bur Oak (*Quercus macrocarpa*) is present at the eastern edge of the Island. The lack of spreading lower limbs indicates that the forest was present before the Bur Oaks became established.

The herbaceous vegetation is typical of eastern dedicuous forests, and of southwest Michigan as well (Table 2). However, at least one dominant species, the White Trout Lily (*Erythronium albidum*), has a more midwesterly distribution (Fig. 3). Similarly distributed Blue-eyed Mary (*Collinsia verna*) also previously occurred in the Island as well as in other locations on Prairie Ronde (Hanes, 1944) but is no longer present. Hanes (1944) also reported

TABLE 2. Comparison of the herbaceous vegetation at the Island (a), Gillet Hill (b), and Cooper's Glen (c). Density (number per acre), Frequency (%). *–indicates presence.

	Density			Frequency			Relative Density		Relative Frequency		Abundance	
Species	a	b	c	a	b	c	a	b	a	b	a	b
Claytonia virginica	42.1	24.5	41.6	88.4	85.7		12.7	9.5	21.4	12.7	47.5	28.5
Dicentra cucularia	24.0	10.0	111.7	70.4	46.4		7.3	3.9	17.0	6.9	34.1	21.6
Floerkia proserpinacoides	225.7	97.6	5.8	52.1	39.3		68.2	38.0	12.6	5.8	433.2	248.4
Osmorhiza claytoni	12.2	1.1	8.5	76.1	25.0		3.7	.43	18.4	3.7	16.0	4.4
Erythronium albidum	9.9			7.0			3.0		1.7		140.0	
Erigenia bulbosa	9.2			26.8			2.8		6.5		34.4	
Hydrophyllum canadensis	8.4	*		47.2			46.1		18.1		17.8	
Dentaria laciniata	3.6	16.1	3.7	22.5	42.9		1.1	6.3	5.4	6.4	15.9	14.1
Dicentra canadensis	3.1	21.3	206.1	39.4	35.7		.9	8.3	9.5	5.3	7.9	14.4
Polygonum persicaria	1.8			22.2			9.9		8.5		8.1	
Circaea quadrisulcata	.9		*	4.2			4.7		1.6		20.7	
Podophyllum peltatum	.83	.1	*	9.9	3.6		.3	.1	2.4	.5	8.4	4.0
Allium tricoccum	.7	*	9.0	14.1			.2		3.4		4.6	
Polygonatum pubescens	.6		2.4	18.1			3.2		6.9		3.2	
Smilacina racemosa	.4		.2	15.3			2.1		5.9		2.5	
Arisaema triphyllum	.3			8.3			1.6		3.2		3.5	

TABLE 2 (Continued)

	Density			Frequency			Relative Density		Relative Frequency		Abundance	
Species	a	b	c	a	b	c	a	b	a	b	a	b
Impatiens biflora	.2			8.3			1.1		3.2		2.5	
Phryma leptostachya	.2		*	11.2			.9		4.2		1.5	
Sanicula marilandica	.2		17.4	2.8			.8		1.1		5.5	
Geum laciniatum	.1			2.8			.4		1.1		2.5	
Galium aparine	.1	.3	4.3	7.0	17.9		.02	.1	1.7	2.7	1.0	1.8
Ribes sp.	.01		*	1.4			.1		.5		1.0	
Erythronium americanum	*		35.3									
Laportea canadensis	*	9.7	.3		64.3			3.8		9.5		15.1
Blephilia hirsuta	*											
Dryopteris spinulosa	*		*									
Asplenium platyneuron		*										
Phlox divaricata	*		1.7									
Cardamine bulbosa	*											
Trillium grandiflorum	*		1.6									
Carex sp.	*											
Hydrophyllum appendiculatum	*		7.8									
Viola cucullata	*											
V. pubescens	*		1.9									
V. papilionacea	*		1.5									
Collinsia verna		*										
Sanguinaria canadensis		3.9	*		28.6			1.5		4.2		13.5
Trillium recurvatum		3.46			39.3			1.35		5.8		8.8
Mertensia virginica		3.2			17.9			1.2		2.7		17.8
Delphinium tricorne		.7			7.1			.3		1.1		10.0
Isopyrum biternatum		38.4			53.6			14.9		7.9		31.9
Asarum canadensis		9.6			39.3			3.8		6.4		24.5

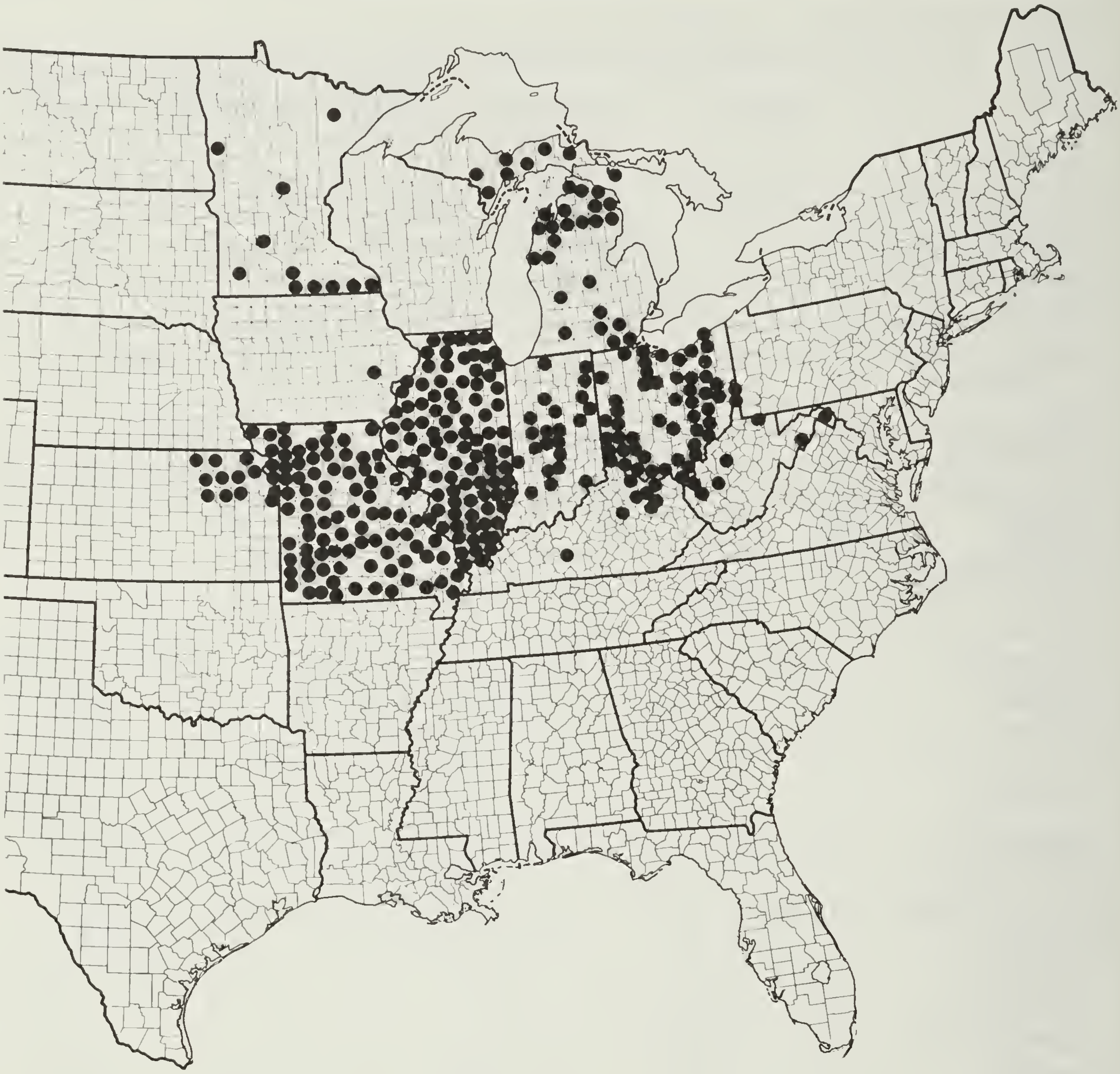

Fig. 3. Distribution of the white trout lily, *Erythronium albidum*, compiled from numerous published works and herbarium specimens.

Bloodroot (*Sanguinaria canadensis*) and the Green Dragon (*Arisaema dracontium*), but these also are no longer present.

DESCRIPTION OF GILLET HILL

The topography of the Gillet Hill vicinity is mostly flat with the nearest comparable hill, Walnut Hill, four miles to the southwest. All other surrounding uplands appear to be adjacent to rivers. The only bodies of water within five miles of Gillet Hill are two small rivers: Lake Fork, running north-south about five miles east, and Wolf Creek, running northwest-southeast four miles southwest of Gillet Hill. Gillet Hill is one of several relatively high, isolated areas in central Illinois. It rises from the surrounding land surface an average of 175 feet, sloping about 20 feet every 215 feet. The crest of the hill follows a southwest-northeast line for approximately 1.5 miles. Although there are few similar hills in the vicinity, there are no crests or ridges indicating that they were ever connected following the last glacial retreat.

The water table at Gillet Hill is considerably lower than at the Island. However, abundant humus together with a dense canopy maintain wet conditions in the herbaceous level throughout the day. Braun (1950) described the soil of central Illinois as glacial outwash. Alluvial material 50-200 feet thick covers the general area around Gillet Hill (Willman *et al.,* 1967). A soil profile indicates a 6- to 7-inch layer of dark-brown loam underlain by yellow-gray soil similar to the Island. Over both soil layers is an 8- to 10-inch layer of humus.

Most of the mature trees sampled on the southwest slope are very large and provide a dense canopy. Sugar Maple (*Acer saccharum*), oak (*Quercus* sp.), Black Walnut (*Juglans nigra*), American Elm, and Basswood are the dominant species (Table 1). Maple and elm are exceptionally abundant. Hackberry and Basswood are widely scattered and much less abundant. Both Blue Ash and White Ash are present only as seedlings and saplings. Paw Paw is very abundant. However, about half of the Paw Paws are less than 1 inch dbh. Black Maple, *Acer nigrum,* and hybrids of *A. saccharum* and *A. nigrum* are present and fairly abundant. Honey-locust (*Gleditsia triacanthos*), Red Bud (*Cercis canadensis*), and Kentucky Coffeetree (*Gymnocladus dioica*) are also present as minor but distinct southern forest components. Basswood, while relatively abundant at the Island, is much less so at Gillet Hill. No Bur Oak was located. The composition of the east-southeast slope is very similar to that of the southwest slope. Maple, walnut and oak are again the largest trees forming an incomplete canopy.

The herbaceous vegetation is definitely mesic and consists of many of the same species found at the Island. Some of the more important ones are: Spring Beauty (*Claytonia virginica*), False Mermaid (*Floerkea proserpinacoides*), Toothwort (*Dentaria laciniata*), Squirrel-Corn (*Dicentra canadensis*), Dutchman's Breeches (*D. cucullaris*), Sweet Cicely (*Osmorhiza claytoni*), May Apple (*Podophyllum peltatum*), and Rough Bedstraw (*Galium aparine*). Other typical southern forest components are Bluebells (*Mertensia virginica*), Red Wake Robin (*Trillium recurvatum*), Larkspur (*Delphinium tricorne*) and Blue-eyed Mary (*Collinsia verna*). Extensive carpets of Bluebells cover many of the higher slopes facing all directions. False Mermaid is found in large, interrupted, extremely dense patches, especially on southern slopes. Wood Nettle (*Laportea canadensis*) is dominant at the base of slopes and in wetter depressions.

DISCUSSION

The woodlands of the prairie peninsula are considered to be mixed forest communities that show considerable variation in specific composition both within and among stands (Braun, 1950). However, by comparison of the woody vegetation of the Island, Gillet Hill, and Cooper's Glen, distinctive relationships develop (Table 3). Sixty-seven percent of the trees occurring at Gillet Hill occur at the Island; those not occurring at the Island are minor components of more southern forests. Fifty-two percent of the trees occurring

TABLE 3. Trees present at the Island (a), Gillet Hill (b), and Cooper's Glen (c).

Species	a	b	c	Species	a	b	c
Acer nigrum	x	x		Hamamelis virginiana			x
A. saccharum	x	x	x	Juglans nigra	x	x	
Acer nigrum ×A. saccharum	x	x		Liriodendron tulipifera			x
Aesculus glabra	x			Morus rubra	x		
Asimina triloba	x	x	x	Ostrya virginiana	x		x
Carya ovata	x		x	Platanus occidentalis	x		
Cercis canadensis		x		Prunus serotina	x		x
Celtis occidentalis	x	x	x	Quercus alba	x		
Cornus florida			x	Q. borealis			x
Fagus grandifolia			x	Q. macrocarpa	x		
Fraxinus americana	x	x	x	Tilia americana	x	x	x
F. nigra			x	Ulmus americana	x	x	
F. quadrangulata	x	x		U. rubra	x		
Gleditsia triacanthos		x		Unknown sp.		x	
Gymnocladus dioica		x					

at the Island occur at Gillet Hill; those not occurring at Gillet Hill are minor constituents of the Island. By comparison, only 42 percent of the trees occurring at the Island occur at Cooper's Glen. (Significant species not occurring at Cooper's Glen are Blue Ash, Black Maple, and Bur Oak.) However, 75 percent of the trees at Cooper's Glen occur at the Island.

Several authors have described isolated prairie groves in different sections of the prairie peninsula. Surveys by Gleason (1909) and Woodward (1925) in Champaign County, Illinois, described upland associations very similar to those at the Island and Gillet Hill. McDougall (1925) also described a mixed hillside forest in Vermillion County, Illinois, including essentially the same major and minor species as those at the Island and Gillet Hill. In Iowa, although forest communities tend to be mostly maple-basswood, Black Maple tends to replace Sugar Maple in the central Iowa forest association (Aikman & Smelser, 1938).

The Island topography is substantially lower than that of Gillet Hill. However, isolated forest groves on prairie bluffs with relief of six feet or less reportedly occur in Champaign County 50 miles east of Gillet Hill (Woodward, 1925). Topographic differences in themselves apparently do not limit the occurrence of prairie groves within the peninsula.

Transeau (1935) outlined the parameters and critical climatic boundaries associated with the peninsula, suggesting that evaporation characteristics appear to be the overriding reason for the occurrence of the prairie peninsula. Braun (1950) stated that the low relative humidity within the prairie peninsula in summer limits the development of mesophytic forests except in local situations. Wells (1965), however, offered the eroding of escarpments as a reason for the occurrence of local forest development.

The growth and occurrence of tree seedlings at the Island, Gillet Hill, and Cooper's Glen indicate perpetuation of each association (Table 4). The presence and absence of key seedling species in each respective stand may be even more indicative of the relationship between stands than the mature trees

TABLE 4. Comparison of the tree seedlings at the Island (a), Gillet Hill (b), and Cooper's Glen (c). Density (number per quadrat), Frequency (%). * indicates presence.

	Density			Frequency			Relative Density		Relative Frequency		Abundance	
Species	a	b	c	a	b	c	a	b	a	b	a	b
Acer saccharum	.36	2.5	22.6	26.4	40.0	98.0	42.7	68.8	10.1	38.7	1.4	6.2
Prunus serotina	.26		.04	9.7		30.0	.31		3.7		2.7	
Ulmus americana	.06	.03	.12	4.2	3.3	48.0	6.5	9.0	1.6	3.2	1.3	1.0
Asimina triloba	.06	.20	.01	5.6	20.0	2.0	6.5	.06	2.1	19.4	1.0	1.0
Fraxinus americana	.03		.15	2.8		.34	3.3		1.1		1.0	
Tilia americana	.01	*	.05	1.4		18.0	1.7		.5		1.0	
Acer nigrum		.6			23.3			16.5		22.6		2.6
A. saccharum × A. nigrum	.06	.26		5.6	10.0		6.5	.07	2.1	9.7	1.0	2.7
Fraxinus quadrangulata		.07			6.7			1.8		6.5		1.0
Fagus grandifolia			.5			56.0						
Carya ovata			.01			28.0						
Cornus florida			.004			8.0						
Quercus borealis			.01			28.0						
Ostrya virginica			.007			8.0						

present (as discussed previously). Furthermore, comparative frequency data indicate major dissimilarities for species such as Sugar Maple, American Elm, and Paw Paw. The preceding parameters may be keys to the identities of these particular associations.

The age of each stand and its use by people must be considered in determining the true quality of the population reproduction. Both Gillet Hill and Cooper's Glen give no indication of ever having been harvested. Many of the trees of both places appear to be at least 200 years old. However, the Island has been harvested and grazed, and its former composition is perhaps indicated only by the oldest trees along fence rows and property lines. High density values in Table 1 indicate that the Island is not a mature stand. Nevertheless, the seedlings growing there are definitely similar to fence row trees and to trees historically present (Hanes, 1944). Seedling lists of forest communities in Iowa (Aikman & Smelser, 1938) indicate a close developmental similarity in presence and proportion to Gillet Hill and the Island.

The above information supports the following concepts: (1) that Gillet Hill is unique and possibly a climax community whereas the Island is re-establishing itself as an association very similar to that at Gillet Hill and (2) that the Island prairie grove became established in Michigan in association with the prairie peninsula where conditions were suitable for its development.

SUMMARY

The Island woodlot appears to be more closely related to Gillet Hill and other isolated prairie groves of north-central Illinois than to the typical beech-maple

forests of southwestern Michigan as indicated by systematic sampling. These woodlands including the Island in southwest Michigan, isolated on former prairie sites, appear to be a cross-sectional composite of northern-midwestern, eastern, and southern forest elements. Analysis of the three woodlands is based on the presence of characteristic woody species in each stand. The combination of certain dominant tree species as well as less conspicuous tree species such as American Elm, Hackberry, Basswood, Black Maple, Blue Ash, and Paw Paw, which are characteristic of prairie groves, strengthen the concept that the Island woodland is more similar to prairie groves than to surrounding Beech-Maple associations. Tree seedling data indicate perpetuation of each association. Herbaceous data are given, but they are not comparable since each site was sampled at different times.

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AN OVERLOOKED CLADONIA NAME IN NORTH AMERICA

Richard C. Harris

University Herbarium, University of Michigan
Ann Arbor, 48109

Cladonia invisa Robb. *in* Allen (Rhodora 32: 92. 1930) is well named, for it has remained "unseen" since its description. It is not mentioned in Thomson's (1967) monograph, nor is it included in either of the supplementary volumes of Zahlbruckner's Catalogus Lichenum Universalis (1931-1940) and has not been subsequently indexed by Lamb (1963) or Hale & Culberson (1970). The holotype (Valley of the Cap Chat River, Matane County, Quebec. Collected by A. F. Allen, July 22, 1928, FH) consists of only a dozen or so squamules and a few podetia growing scattered on two small pieces of wood. The wood is covered with a thin algal film indicating a moist habitat. Although Robbins noted that *C. invisa* differs from *C. caespiticia* (Pers.) Flörke in several respects, after examining a number of specimens of the latter, I could find no differences which might not be attributable to the unusual habitat in which *C. invisa* was growing. *Cladonia caespiticia* is usually found on soil, often among mosses, forming compact cushions. Apparently the moist ligneous substrate has led to the squamules growing in a more scattered manner. I was not able to see that their form differs much from normal *C. caespiticia.* The podetia are a little longer than typical, and the apothecia are poorly developed giving them a slightly atypical aspect. They are ecorticate as in *C. caespiticia* and are very similar to immature podetia of this species. Thin-layer chromatography (Eastman 13181, benzene:dioxane:acetic acid, 90:25:4) of fragments of *C. invisa* showed the presence of only fumarprotocetraric acid, which is also the only lichen acid of *C. caespiticia.* Since there are no significant differences, *Cladonia invisa* should be regarded as conspecific with *C. caespiticia.*

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MICHIGAN PLANTS IN PRINT

New Literature Relating to Michigan Botany

A. MAPS, SOILS, GEOLOGY, CLIMATE, GENERAL

Buckler, William R., & Harold A. Winters. 1976 ["1975"]. Rates of bluff recession at selected sites along the southeastern shore of Lake Michigan. Mich. Academ. 8: 179-186. [Data on 7 sites from the 1830's to 1973 between Muskegon and Berrien cos.; vegetated bluff slopes are a result of bluff stability, not a cause of it.]

Engberg, Clarence A., & Franklin R. Austin. 1974. Soil Survey of Livingston County, Michigan. U.S. Dep. Agr. 92 pp. + 44 once-folded map plates + [8] pp. index, legends, etc. [Includes background information and general soil map as well as complete aerial photographic coverage of the county with cultural features and boundaries of soil types superimposed. Photography dates from 1971 and the scale is ca. 3″ = 1 mile. Available from Soil Conservation Service, U.S.D.A., 1405 Harrison Rd., East Lansing, Michigan 48823. A welcome replacement for the old survey of this county, done in 1923.]

Farrand, William R. 1976. Was there really a Valders? Mich. Academ. 8: 477-486. [Discusses problems of nomenclature and correlation of till assigned to the most recent glacial advance in the western Great Lakes region.]

Heinrich, E. Wm. 1976. The Mineralogy of Michigan. Mich. Geol. Surv. Bull. 6. 225 pp. $3.00. [Following general information including historical introduction, minerals are described in alphabetical order, with information on sites and many illustrations.]

Saarnisto, Matti. 1974. The deglaciation of the Lake Superior region and its climatic implications. Quat. Res. 4: 316-339. [History of the lake and associated moraines, with pollen profiles from Ontario.]

Schneider, James C. 1975. Typology and fisheries potential of Michigan lakes. Mich. Academ. 8: 59-84. [Includes information on lake surveys, distribution of lakes by alkalinity type, geologic and other classifications of lakes, etc.]

Willis, Gary L., Eric A. Bourdo, & C. Richard Crowther. 1975. Throughfall and Stemflow in a Northern Hardwood Forest. Mich. Tech. Univ. Ford For. Center Res. Note 16. 12 pp. [Study during 6 seasons of rainfall patterns beneath forest canopy "just west of the village of Alberta . . . approximately 10 miles south of Lake Superior"; site not otherwise located as to state or county (Baraga Co., Mich.).]

Wright, H. E., Jr. 1971. Retreat of the Laurentide ice sheet from 14,000 to 9000 years ago. Quat. Res. 1: 316-330. [Considers 3 principal readvances of glacial ice at about 14,500, 13,000, and 11,500 years ago (Cary, Port Huron, Valders).]

(U.S. Geological Survey). The following topographic maps for Michigan have been published since the previous listing in our March 1975 issue and are available at $1.25 each from Branch of Distribution, U.S. Geological Survey, 1200 South Eads St., Arlington, Virginia 22202. Maps are supplied folded unless unfolded copies are requested. All listed here are 7½-minute quadrangles (scale of 1:24,000 or about 2½ inches to a mile) and are new or resurveyed, except those marked with an asterisk, which are photorevisions (not field-checked). Following the name of the quadrangle, the county or counties in which it primarily lies are added.

Adair* [St. Clair]
Ahmeek* [Keweenaw, Houghton]
Alcona Dam Pond [Alcona]
Alma North [Gratiot, Isabella]
Alma South [Gratiot]
Armada* [Macomb]
Beacon Hill* [Houghton]
Beaver Lake [Alpena]
Big Ravine Creek [Alpena]
Birch Run South* [Genesee, Saginaw]
Blaney Park [Schoolcraft]
Blissfield [Lenawee]
Borculo [Ottawa]
Brighton* [Livingston]
Brimley* [Chippewa]
Bruneau Creek* [Keweenaw]
Byron* [Shiawassee, Genesee, Livingston]
Chassell* [Houghton]
Clarkston* [Oakland]
Clio* [Genesee, Tuscola, Saginaw]
Corunna [Shiawassee]
Corunna SE [Shiawassee]
Curran [Alcona]
Curtis West [Mackinac]

Davisburg* [Oakland]
Davison* [Genesee]
Deerfield [Lenawee]
Deer Lake* [Keweenaw]
Delaware* [Keweenaw]
Driggs Lake [Schoolcraft]
Driggs Lake SE [Schoolcraft]
Dundee [Monroe]
Eagle Harbor* [Keweenaw]
Evans Creek [Alpena]
Fairview [Oscoda]
Fenton* [Oakland, Genesee, Livingston]
Flint North* [Genesee]
Flint South* [Genesee]
Flushing* [Genesee]
Fort Wilkins* [Keweenaw]
Gay* [Keweenaw, Houghton]
Germfask [Schoolcraft]
Goodar [Oscoda]
Goodrich* [Genesee]
Grand Haven [Ottawa]
Graveraet River* [Houghton]
Grosse Pointe* [Macomb, Wayne]
Gulliver [Schoolcraft]
Hancock* [Houghton]
Hardwood Island [Luce]
Hartland* [Livingston]
Highland* [Oakland]
Holland East [Ottawa]
Holland West [Ottawa]
Howell* [Livingston]
Hubbard Lake [Alcona]
Hubbard Lake SW [Alcona]
Hughes Point [Mackinac]
Inkster* [Wayne]
Island Lake [Oscoda]
Kent Lake* [Livingston, Oakland]
Lake Medora* [Keweenaw]
Lake Orion* [Oakland]
Lambertville East [Monroe]
Lambertville West [Monroe]
Laurium* [Houghton]
Linden* [Genesee, Livingston]
Mack Lake [Oscoda]
Manistique East [Schoolcraft]
Marine City* [St. Clair]
Marsh Creek Pool [Schoolcraft]
Marsh Creek Pool NW [Schoolcraft]
McCollum Lake [Oscoda]
McGinn Creek [Alcona]
McKinley [Oscoda]
Merwin Lake [Schoolcraft]
Milakokia Lake [Mackinac]
Milford* [Oakland]
Mio [Oscoda]
Mohawk* [Keweenaw, Houghton]
Montrose* [Saginaw, Genesee]
Mt. Clemens East* [Macomb]
Mt. Clemens West* [Macomb]
Muggin Creek* [Houghton]
New Baltimore* [St. Clair]
New Haven* [Macomb]
New Lothrop* [Shiawassee, Genesee]
Nunica [Ottawa]
Oak Grove* [Livingston]
Ortonville* [Oakland]
Oskar* [Houghton]
Otisville* [Genesee, Tuscola]
Owosso South [Shiawassee]
Oxford* [Oakland]
Palmyra [Lenawee]
Perry [Shiawassee]
Point Isabelle* [Keweenaw]
Point Mills* [Houghton]
Pontiac North* [Oakland]
Pontiac South* [Oakland]
Port Sheldon [Ottawa]
Redford* [Oakland, Wayne]
Rice Lake* [Houghton, Keweenaw]
Richmond* [Macomb]
Rochester* [Oakland]
Rockhouse Point* [Houghton, Ontonagon]
Rockwood* [Wayne]
Romeo* [Macomb]
Royal Oak* [Oakland, Wayne]
Rust [Montmorency]
Salem* [Oakland, Washtenaw]
Seney [Schoolcraft]
Seney NW [Schoolcraft]
Seul Choix Point [Schoolcraft]
Shepherd [Isabella]
Smith Lake [Schoolcraft]
Smiths Creek* [St. Clair]
South Lyon* [Livingston, Washtenaw]
South Range* [Houghton]
Stony Point* [Monroe]
Sullivan [Muskegon]
Sunken Lake [Schoolcraft]
Swartz Creek* [Genesee]
Tahquamenon Lakes [Luce]
Tecumseh South [Lenawee]
Traverse Island* [Houghton]
Utica* [Macomb]
Waldenburg* [Macomb]
Walled Lake* [Oakland]
Walsh [Schoolcraft]
Warren* [Macomb]
Wayne* [Wayne]
West Highland* [Livingston, Oakland]
Ypsilanti East* [Washtenaw, Wayne]

C. JOURNAL ARTICLES

Bricker, F. James, & John E. Gannon. 1976. Limnological investigation of Hoop Lake–A northern Michigan bog. Mich. Academ. 8: 25-42. [Includes data on phytoplankton as well as physical characteristics of a bog in Cheboygan Co., with map.]

Brubaker, Linda B. 1975. Postglacial forest patterns associated with till and outwash in northcentral upper Michigan. Quat. Res. 5: 499-527. [Study with pollen profile in area of Huron Mountains.]

Coffman, Michael S., & Nancy J. Hall. 1976. The use of plant indicator species to predict productivity in red pine plantations. Mich. Academ. 8: 157-172. [Includes data on ground flora established in pine plantations of the western Upper Peninsula.]

Davis, M. B., L. B. Brubaker, & J. M. Beiswenger. 1971. Pollen grains in lake sediments: Pollen percentages in surface sediments from southern Michigan. Quat. Res. 1: 450-467. [Samples studied from 7 lake basins, mostly in Washtenaw Co.; presents evidence for differential deposition of herb pollen and more uniform deposition of tree pollen.]

Hill, Royce H. 1976. Effects of light preconditioning on growth form, CO_2 exchange, and transpiration of three fern species of southeastern Michigan. Mich. Academ. 8: 203-216. [Study of plants from 3 sites in Washtenaw Co.]

Jaworski, Eugene, & C. Nicholas Raphael. 1976. Modification of coastal wetlands in southeastern Michigan and management alternatives. Mich. Academ. 8: 303-317. [Includes diagrammatic vegetation transects on the lower St. Clair River delta (Harsens Island) and maps of wetlands in both past and present times at Lake St. Clair, Raisin River, and North Maumee Bay.]

Long, Charles Alan, & Charles A. Long. 1976. Some amphibians and reptiles collected on islands in Green Bay, Lake Michigan. Jack-Pine Warbler 54: 54-58. [Includes brief description of vegetation on Little Summer Island and Poverty Island (Delta Co.), with reference also to St. Martin and Summer islands.]

Löve, Askell. 1976. IOPB chromosome number reports LI. Taxon 25: 155-164. [Includes counts on 26 miscellaneous species of flowering plants from Allegan and Ottawa cos., by P. Van Faasen and P. Nadeau.]

Solbrig, Otto T., & Beryl B. Simpson. 1974. Components of regulation of a population of dandelions in Michigan. Jour. Ecol. 62: 473-486. [Laboratory studies on plants from various sites at the Matthaei Botanical Gardens of The University of Michigan.]

Trappe, James M. 1975. A revision of the genus Alpova with notes on Rhizopogon and the Melanogastraceae. Beih. Nova Hedwigia 51: 279-309. [*A. diplophloeus* cited from Michigan.]

Vitt, Dale H., & Catherine D. Hamilton. 1975. Taxonomic status of Tomenthypnum falcifolium. Bryologist 78: 168-177. [*T. nitens* cited from Presque Isle Co.]

Wagner, Warren H., Jr. 1974. Structure of spores in relation to fern phylogeny. Ann. Missouri Bot. Gard. 61: 332-353. [Contains some data from Michigan, including footnote on times of spore release.]

Webb, Thompson, III, & Reid A. Bryson. 1972. Late- and postglacial climatic change in the northern Midwest, USA: Quantitative estimates derived from fossil pollen spectra by multivariate statistical analysis. Quat. Res. 2: 70-115 [Some data from Michigan samples.]

Weimarck, Gunnar. 1971. Variation and taxonomy of Hierochloë (Gramineae) in the northern hemisphere. Bot. Not. 124: 129-175. [*H. hirta* ssp. *arctica* is the only taxon indicated in Michigan (map and text).]

Welsh, Stanley Larson. 1960. Legumes of the North-Central states: Galegeae. Iowa St. Jour. Sci. 35: 111-249. [Maps show locations in Michigan for *Astragalus americanus, A. cooperi, Robinia hispida, R. viscosa, R. pseudoacacia, Tephrosia virginiana.* A well illustrated treatment of this tribe, with keys, full descriptions, and synonymy.]

Werner, Patricia A., & Judith D. Soule. 1976. The biology of Canadian weeds. 18. Potentilla recta L., P. norvegica L., and P. argentea L. Canad. Jour. Pl. Sci. 56: 591-603. [Distribution maps for Canada and adjacent U.S. show all three species more or less throughout the Lower Peninsula and local in the Upper Peninsula. Most of the data on community composition, phenology, floral biology, and population dynamics are from Kalamazoo Co.]

Woodson, Robert E. 1964. The geography of flower color in butterflyweed. Evolution 18: 143-163. [Includes some information on flower color in Michigan, with symbols on distribution map.]

REVIEW

ONCE AROUND THE SUN: A DOOR COUNTY JOURNAL. By Roy Lukes. Pine Street Press, Baileys Harbor, Wisconsin. 1976. 216 pp. Cloth: $8.95.

Originally published as short newspaper articles, these nature sketches take one pleasantly around the year, observing the plant and animal life of Door County, Wisconsin. Nicely bound and attractively illustrated with soft pencil drawings by the author's wife, Charlotte, this book may be especially appealing to those familiar with the area.

—Ruth Alford

The March issue (Vol. 16, No. 2) was mailed April 7, 1977.

CONTENTS

Endangered, Threatened, and Rare Vascular Plants in Michigan
W. H. Wagner, E. G. Voss, J. H. Beaman, E. A. Bourdo, F. W. Case, J. A. Churchill & P. W. Thompson 99

Commentary on Endangered and Threatened Plants in Michigan
John H. Beaman 110

Several Interesting *Fontinalis* Collections in Houghton County, Michigan
Janice M. Glime & Stephen E. Trynoski 123

Additions and Corrections to the List of Vascular Plants from the Douglas Lake Region, Michigan 126

Crown Position and Heterophylly in White Oak
Richard R. Braham 141

A Prairie Grove in Southwest Michigan
Michael Fleckenstein & Richard W. Pippen 147

An Overlooked Cladonia Name in North America
Richard C. Harris 159

Michigan Plants in Print 160

Review 163

On the cover: Dwarf Lake Iris (Iris lacustris) *at Grass Bay, Cheboygan County, Michigan, June 15, 1969. (From a color transparency by E. G. Voss.)*

33
,16
,4

Vol. 16, No. 4

THE
MICHIGAN BOTANIST

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SOME VERY COMMON GRASSES

Winifred O. Moore
1003 Brooks St.,
Ann Arbor, Michigan 48103

The grasses described here are common at roadsides and in lawns, gardens, and vacant lots in southeastern Michigan and in a much wider area. The descriptions are intended for non-professionals whose equipment may be limited to a magnifying glass, or a handlens, and a ruler.

Grasses are wind-pollinated plants that lack petals and sepals but have stamens and pistils. They are seasonal in their time of flowering, and for this reason the ones described here are grouped according to their blooming period, in the spring, early summer, and late summer. While there is some overlap, one no more expects to find brome grass blooming in the fall than bloodroot in August.

A common name is given for every grass, but it is well to remember that the same name may be applied to several species. Wire grass and foxtail, for example, are used for several quite different grasses.

The described grasses are sufficiently distinct that even a handlens should seldom be needed. Terms peculiar to the description of grasses sometimes give trouble but are useful when understood. The *inflorescence* is that part of the grass bearing the flowers and may be a *spike* (Fig. 1*a*), a *raceme* (Fig. 1*b*), or a *panicle* (Fig. 1*c*). The unit of the inflorescence is the *spikelet* (Fig. 1*d*) consisting of two *glumes* (Fig. 1*e*) borne below one or more florets. The glumes are empty bracts. The *florets* (Fig. 1*f*) are individual grass flowers with enclosing bracts. The outer and usually larger one is called the *lemma* (Fig. 1*g*) and the inner, which encloses the stamens and pistil, is called the palea (Fig. 1*h*). The word lemma is from the Greek and means shell or husk, and palea is from the Latin and means chaff. Some glumes and lemmas are laterally flattened, making them boat-shaped, and the fold is compared to a boat's *keel* (Fig. 1*l*).

Often the principal veins, called *nerves* (Fig. 1*m*), of the glumes, lemmas and paleas are large enough to be plainly seen. Sometimes the central nerve is extended as a point or bristle and is called an *awn* (Fig. 1*i*). When such awns are hard and sharp they may be dangerous to livestock, wounding mouths and intestinal tracts when eaten.

The stem is called a *culm* (Fig. 1*o*), an old botanical term from the Latin word for stalk. The joints are called *nodes* (Fig. 1*n*). The expanded flat part of the grass leaf is called the *blade* (Fig. 1*p*), and the part enclosing the culm is the *sheath* (Fig. 1*k*). At the base of the blade where it encloses the culm and becomes the sheath, there is often a thin collar-like tissue called the *ligule* (Fig. 1*j*), from the Latin for little tongue.

An important feature of many grasses is their habit of forming *rhizomes,* underground stems, often horizontal and sometimes mistaken for roots. Also, *stolons* may be developed, that is, stems creeping along the surface of the ground and often rooting at the nodes.

Hitchcock's *Manual* lists 1398 different species, why then list here a mere 22? The reason is that these species are easily found and a knowledge of them can form the basis for the identification of others. These 22 can probably be found within easy reach of the reader. I found all of them within the city limits of Ann Arbor, though I must say that I was startled to come upon a luxuriant stand of reed canary grass in the corner of a parking lot!

Agnes Chase's *First Book of Grasses* will prepare one to use the manuals of other authors. Unfortunately, it is not easy to obtain. A substitute might be Pohl's *How to Know the Grasses,* which is prefaced by an illustrated review of structure, as well as information on collecting. Fernald (1950), Gleason (1952), Hitchcock (1951), and Voss (1972) are a little overwhelming for the beginner, though Voss, by limiting himself to Michigan, brings the number down to a more comprehensive level. Gleason's work is fully illustrated and therefore very helpful. The *Agricultural Yearbook* (1948) has interesting notes on pasture and feed grasses, and Muenscher's *Weeds* (1935) discusses species less useful to man, frequently those found along waysides.

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1.	Inflorescence of spiny burs; in late summer	18. *Cenchrus longispinus*
1.	Inflorescence not burs	2
2.	Height usually less than 20 cm (8 in)	3
2.	Height usually more than 20 cm	4
3.	Blades usually 4 cm (1½ in) or more long, with boat-shaped tips; glumes 1.2 to 2.5 mm (1/16 to 1/8 in); lemmas without awns; spring	1. *Poa annua*
3.	Blades usually 2.5 to 5 cm (1 to 2 in) long, with flat, pointed tips; glumes inconspicuous or absent; lemmas without awns; late summer	22. *Muhlenbergia schreberi*
4.	Inflorescence spike-like	5
4.	Inflorescence an open panicle	12
5.	Inflorescence a spike, a single terminal inflorescence of sessile spikelets	6
5.	Inflorescence not a spike	8
6.	Inflorescence with awnlike glumes; lemmas with awns 5 cm (2 in) or more long; early summer	13. *Hordeum jubatum*
6.	Inflorescence awnless, or if awns are present they are less than 1 cm (½ in) long	7

7. Blades usually 2 to 4 mm (1/16 to 3/16 in) wide; spikelets oriented edgewise to the stem, fitting into stem cavities; only one glume present; spring 6. *Lolium perenne*
7. Blades usually 6 to 10 mm (1/4 to 3/8 in) wide; spikelets oriented broadside to the stem; glumes 2; early summer 14. *Agropyron repens*

8. Inflorescence finger-like clusters of slender spike-like racemes; late summer 16. *Digitaria sanguinalis*
8. Inflorescence a panicle 9

9. Inflorescence a large pyramidal panicle open during flowering, appearing closed and spikelike before and after blooming; early summer 11. *Phalaris arundinacea*
9. Inflorescence a compact, spikelike, cylindrical panicle 10

10. Spikelets surrounded by long, hair-like bristles; late summer 15. *Setaria viridis*
10. Spikelets not surrounded by bristles 11

11. Awns 3.5 to 6 mm (1/8 to 1/4 in) long on lemmas; spring 2. *Alopecurus pratensis*
11. Awns 1 to 2 mm (1/32 to 1/16 in) long on glumes; early summer 9. *Phleum pratense*

12. Panicle of drooping habit; spikelets 12 to 20 mm (1/2 to 3/4 in) long; lemmas with awns 10 to 17 mm (3/8 to 3/4 in) long; spring 3. *Bromus tectorum*
12. Panicle not particularly drooping 13

13. Awns more than 1 mm (1/32 in) long 14
13. Awns none or very short 15

14. Blades less than 4 mm (3/16 in) wide; several florets in a spikelet; early summer 8. *Festuca rubra*
14. Blades 5 to 15 mm (3/16 to 9/16 in) wide; panicle of densely flowered racemes; only one fertile floret in a spikelet; late summer 20. *Echinochloa crusgalli*

15. Spikelets containing more than one fertile floret 16
15. Spikelets containing only one fertile floret 20

16. Blades usually less than 4 mm (3/16 in) wide 17
16. Blades usually more than 4 mm wide 18

17. Panicle branches usually in whorls of 4 and 5; stems round; web of cottony hairs at the base of the floret; spring 5. *Poa pratensis*
17. Panicle branches usually in pairs; stems flattened and wiry; no, or very scant, webbing at base of floret; early summer 12. *Poa compressa*

18. Spikelets crowded in dense tufts on one side of the panicle branches; spring 4. *Dactylis glomerata*
18. Spikelets not crowded in tufts 19

19. Blades with wart-like glands on the edges; ligule a fringe of hairs; late summer 17. *Eragrostis cilianensis*
19. Blades without wart-like glands; ligule a membrane; late summer 7. *Festuca pratensis*

20. Leaves hairy; ligule of fine hairs; panicle having a plume-like appearance when flowering, expanding into a fragile sphere on maturing; late summer 19. *Panicum capillare*
20. Leaves not hairy; panicle not as above 21

21. Panicle branches club-like, densely crowded with spikelets 22
21. Panicle not as above 23

22. Panicle green to dark brown; ligule absent; late summer 20. *Echinochloa crusgalli*
22. Panicle white or purple tinged; ligule large; early summer 11. *Phalaris arundinacea*

23. Panicle open, pyramidal with whorls of many branches; reddish, having a lacy, fragile appearance; stems solitary; early summer 10. *Agrostis gigantea*

23. Panicle somewhat contracted, green to purplish; plant bushy in appearance with several panicles on a stem; late summer 21. *Muhlenbergia frondosa*

SPRING GRASSES

Blooming time late April through June

1. ANNUAL BLUEGRASS (*Poa annua*), also called six weeks grass and dwarf speargrass. Fig. 3. Quite early in spring—late April or early May—this annual grass forms low, bright-green, spreading tufts and puts out short flowering stems 5 to 20 cm (2 to 8 in) tall with oval to pyramidal panicles. Leafy stems have a tendency to root at the lower nodes. The narrow *blades,* up to 3 mm (1/8 in) wide, have boat-shaped tips and loose sheaths. The *panicles*, which vary from 2 to 8 cm (3/4 to 3 in) in length, are rather sparsely branched and bear spikelets crowded above the middle of the branches. The *spikelets* are about 4 mm (3/16 in) long and have 3 to 6 florets each. The *glumes* are shorter than the lowest floret, 1.5 to 2.5 mm (1/16 to 1/8 in) long, keeled, unequal in length and awnless. The lemma is awnless and has a slightly hairy but not cobwebby base.

The small, short, pale-green panicles show up well against the darker green blades. The dense tufts show as bright green patches in garden beds where they have started growing in early spring. This grass fills in the lawn nicely and looks lush in spring, but it dies down in hot weather leaving brown and bare spots, hence one of its names, six weeks grass. With a period of cool wet weather it may appear again.

2. MEADOW FOXTAIL (*Alopecurus pratensis*). Fig. 4. A perennial blooming in early May and June, occasionally later. This grass has been seldom collected in Michigan, but this may be because it is often mistaken for timothy since the flowering heads are similar. In this area the inflorescence appears early, the florets ripen and fall before timothy's flower heads show, making comparison difficult. Timothy's inflorescence is stiff and rather smooth, whereas that of meadow foxtail is fuzzy.

Meadow foxtail is a pasture grass found in abandoned fields and vacant lots and at waysides; it is generally a moist-land grass. It is perhaps the first tall grass to bloom in this area. It grows in loose tufts 30 to 80 cm (1 to 2½ ft) tall with *blades* 2 to 6 mm (1/16 to 1/4 in) wide. The *inflorescence* is a dense, cylindrical, spike-like panicle 3 to 7 cm (1 to 3 in) long. When fully developed the panicle has a fuzzy appearance owing to the long soft awns. The *spikelets,* about 5 mm (3/16 in) long, are flattened, giving both glumes and lemmas a sharp keel and a definite boat-shaped appearance. There is only one *floret* per spikelet. When ripe, the entire spikelet falls from the stalk. The *glumes* are hairy on the keels, joined at the base, and awnless. The *lemma* is as long as the glumes, and its edges are joined at the base to about 1/3 of its length, well enclosing the ovary. There is no palea. The hair-like awn is detached from the middle nerve about a third of the way from the base and is 3.5 to 6 mm (1/8 to 1/4 in) long.

3. DOWNY BROME GRASS (*Bromus tectorum*), also called downy chess and early chess. Fig. 2. This is probably the most common brome grass in this region. It is an annual and may be found in tufts and patches almost anywhere, blooming from middle May through June and sometimes July. Its height varies from 20 to 60 cm (8 in to 2 ft). The immature panicles can often be spotted at a distance by their nodding, shining, bright, light-green appearance. The whole plant is softly hairy and has a velvety feel. It bears some resemblance to the unrelated wild oats (*Uniola latifolia*) and is sometimes so miscalled. The *blades* are 2 to 4 mm (1/16 to 3/16 in) wide. The panicle is 5 to 20 cm (2 to 8 in) long, open, with long slender branches bearing large, drooping, awned *spikelets* 12 to 20 mm (1/2 to 3/4 in) long, excluding the long awns, and often reddish especially when mature. There are 3 to 6 florets in each spikelet. The *glumes* are shorter than the lowest floret. The *florets* are 10 to 12 mm (3/8 to 1/2 in) long with *lemmas* that have *awns* 10 to 17 mm (3/8 to 1/2 in) long. The tip of the lemma is deeply notched, forming two teeth, and the awn rises between the teeth.

4. ORCHARD GRASS (*Dactylis glomerata*), also called cocksfoot. Fig. 7. This is one of the most common grasses in this area, and the persistent flower heads make it recognizable for most of the year. Specimens can be found in flower from May to September, but the principal blooming time is late May and June. It is a good pasture grass and can grow in shady places. A perennial, it grows in large thick clumps which may be as much as 20 to 25 cm (8 to 10 in) in diameter. Quite early in the spring the clumps put out quantities of bright bluish-green leaves about 6 mm (1/4 in) wide. The grass can be recognized at this stage by the clumps with long blades folded lengthwise at the base and resembling small iris leaves. One or two last year's flowering heads may persist and aid in recognition.

The flowering stems grow from 60 to 120 cm (2 to 4 ft) tall and have a few long blades. The *inflorescence* is an open panicle but when developing, and after blooming, it is closed, resembling a thick interrupted spike (Fig. 7*b*), about 5 to 20 cm (2 to 8 in) long. When blooming, the main branches spread almost at right angles to the stem. The *spikelets* are crowded in bunches on one side of branch ends, giving the panicle the appearance of a bird's foot. No other grass in this area has a similar inflorescence. The nearly stemless *spikelets* are about 1 cm (3/8 in) long and have 2 to 6 florets. The *glumes* are keeled and not quite as long as the *lemmas* which are sharp-pointed and sometimes short-awned.

5. KENTUCKY BLUEGRASS (*Poa pratensis*), also called June grass and speargrass. Fig. 5. Blooming principally in May and June, this grass is widely used in lawns and therefore several horticultural varieties have been developed. When growing as a weed it may be confused with redtop, No. 10, and the two fescues, Nos. 7 and 8, but these should not be difficult to distinguish.

Kentucky bluegrass is a perennial spreading by long rhizomes—the feature that makes it a good lawn and pasture grass but also a spreading weed in flower beds. The *blades* are narrow, 2 to 4 mm (1/16 to 3/16 in) wide, folded lengthwise as they rise from the sheaths, with the upper parts flat with boat-shaped tips. Like annual bluegrass, Kentucky bluegrass tends to grow in tufts at first but spreads out in a mat as the rhizomes elongate and send up new shoots. When allowed to develop the flowering stems reach 30 to 100 cm (1 to 3 ft) in height. The *inflorescence* is an open oval to pyramidal panicle, the lower branches tending to be in whorls of 5. The panicle usually contracts after flowering (for contracted panicle see orchard grass, Fig. 7). The *spikelets,* crowded towards the ends of the panicle branches, are 3 to 6 mm (1/8 to 1/4 in) long and have 3 to 5 florets. There are no *awns.* The *glumes* are shorter than the lowest floret and are sharp-pointed and keeled. If the spikelets are taken apart, webs of cottony hairs can be found at the bases of the lemmas.

6. RYEGRASS (*Lolium perenne*), also called common darnel and English ryegrass. Fig. 6. According to the 1948 *Yearbook of Agriculture,* it was the first of all perennial grasses to be grown in pure stands for forage and was mentioned in agricultural literature in England as early as 1611.

This is a winter annual or short-lived perennial, blooming in late May to July. It is sometimes used in lawn mixtures because it grows quickly. For the same reason it is used to give a quick cover on stripped areas. It can grow fairly tall, 30 to 60 cm (1 to 2 ft); it has narrow *blades* 2 to 4 mm (1/16 to 3/16 in) wide. The *inflorescence* is a true spike about 15 to 25 cm (6 to 10 in) long. The *spikelets,* about 1 cm (3/8 in) long, are oriented edgewise to the stem, one side fitting into a cavity on the stem. There are 6 to 10 florets in a spikelet. There is only one *glume,* usually shorter than the lowest floret and oriented on the side of the spikelet away from the stem. The lemmas are typically awnless, but one finds plants with unmistakable awns. This condition may arise as a result of hybridization with *L. multiflorum,* Italian ryegrass, which is similar to perennial ryegrass but larger, with 10 to 20 florets in a spikelet and awns up to 8 mm (5/16 in) long on most of the lemmas.

EARLY SUMMER GRASSES

Blooming time late June through July

7. MEADOW FESCUE (*Festuca pratensis,* formerly known as *F. elatior*). Fig. 11. This is a tall perennial, blooming from June through July, and commonly found in fields and roadsides. It is cultivated in meadows and pastures and can be found as a cover grass along highways. It grows in tufts from 50 to 120 cm (1½ to 4 ft) tall and has flat soft *blades* 3 to 8 mm (1/8 to 5/16 in) wide. Rhizomes, if present, are short. The *inflorescence* is a handsome, open cylindrical panicle 10 to 20 cm (4 to 8 in) long. The branches are mostly one per node; if 2, the second is short and small. After flowering the panicle contracts until it is almost spike-like. The *spikelets* are 8 to 12 mm (5/16 to 1/2 in) long and have 6 to 8 florets. The *glumes* are shorter than the lowest floret. The *lemmas* are sharp-pointed, rarely short-awned.

8. RED FESCUE (*Festuca rubra*). Fig. 12. Like Kentucky bluegrass, red fescue is a perennial widely used as a lawn grass, and several horticultural varieties have been developed from it. In the lawn, long rhizomes usually develop, advantageous in forming a good turf but causing problems in flower beds. A distinctive feature of this grass is the *closed sheath* of the young blades. Older sheaths tend to become dark-red and fibrous. New leafy shoots break through the bases, the plant thus spreading out in a loose turf. The blades are narrow, 1 to 3 mm (1/32 to 1/8 in) wide. (Meadow fescue has wider blades.) The flowering stems, appearing in June and July, are reddish or purplish at the base and may reach 40 to 100 cm (1 to 3 ft) in height. The *inflorescence* is a narrow, contracted panicle with branches mostly erect and ascending. The *spikelets* are 7 to 20 mm (5/16 to 7/8 in) long with 3 to 10 florets and are often purple-tinged. The *glumes* are shorter than the lowest floret. The *lemmas* are usually awned, the awn being about half as long as the lemma, 2 mm (1/16 in) or more.

9. TIMOTHY (*Phleum pratense*). Fig. 13. This important hay-producing grass is easily recognized by its cylindrical, spike-like inflorescence, blooming in June and July. While it is not generally a garden weed, it is common in waste places. It is a tall plant, 50 to 100 cm (1½ to 3 ft) high, a perennial growing in clumps and tufts. The bases of the stems are often swollen and bulb-like. The long *blades* are 5 to 8 mm (3/16 to 5/16 in) wide. The large *ligule* is about 1 mm (1/32 in) or more long. The *inflorescence* is a spike-like, cylindrical panicle, commonly 5 to 10 cm (2 to 4 in) long or more. The crowded *spikelets* are about 5 mm (3/16 in) long and have only one floret. The *glumes* have squared tips with a short *awn* about half as long as the body of the glume. Note that in this grass the glumes, not the lemmas, have awns. The *lemmas* are shorter than the glumes.

10. REDTOP (*Agrostis gigantea,* formerly known as *A. alba*). Fig. 14. This is one of the bentgrasses, several of which are used in lawns, golf courses, and pastures. Redtop is a perennial also found as an escape in vacant lots and garden beds and at roadsides. It is often tall, 1 to 1.5 m (3 to 4½ ft) in height, and is made conspicuous by large, handsome, pyramidal, reddish panicles, up to 20 cm (8 in) long, that give it its name. It blooms mainly in late June sometimes extending through August. It is a perennial with long scaly rhizomes that send up many leafy shoots, making a thick turf. The blades are 3 to 7 mm (1/8 to 5/16 in) wide with large ligules also 3 to 7 mm long. The spreading panicle has dense whorls of branches, usually flowering to their bases. There may be some contraction after flowering. The *spikelets* are about 2 to 3.5 mm (1/16 to 3/16 in) long and have a single perfect floret. The *glumes* are longer than the *lemma,* and there are no awns. This attractive grass is sometimes used in floral arrangements since only the florets fall when ripe, leaving the glumes on the branches.

11. REED CANARY GRASS (*Phalaris arundinacea*). Fig. 9. Although this is usually thought of as a marsh grass, it is frequently seen in wet ditches

and low places along highways. It grows in patches and reaches heights of 60 to 150 cm (2 to 5 ft). Blooming time is from late May to early August, but mostly in June. At the time of flowering, the large whitish panicles are an eye-catcher even from a passing car.

The plant is a perennial and has thick, pinkish rhizomes. The large *blades* are flat, long, and 6 to 20 mm (1/4 to 1 in) wide, and the conspicuous *ligules* are 2 to 4 mm (1/16 to 3/16 in) long. The *inflorescence* is an open panicle 7 to 16 cm (2½ to 7 in) long, pale or lightly tinged with purple, well spread out when flowering, but tightly contracted into a thick spike while maturing. The *spikelets* are short-stemmed and about 4 to 6 mm (3/16 to 1/4 in) long. There is only one fertile floret, but there are usually 2 small staminate or sterile florets below the fertile one. The *glumes* are awnless and longer then the floret. The tiny sterile lemmas are very hairy.

12. CANADA BLUEGRASS (*Poa compressa*), also called wiregrass. Fig. 15. Although the principal blooming time of this grass is June, the fruiting heads can be found into September. It is generally a low perennial grass growing in poor soil. Long slender rhizomes give rise to patches of grass often noticed because of the bluish-green color. The stems are decidedly flattened and wiry. The height of the flowering stem varies from 15 to 70 cm (6 in to 2½ ft). The *blades* are rather short, seldom more than 10 cm (4 in) long, and are 2 to 4 mm (1/16 to 3/16 in) wide. The *inflorescence* is a narrow panicle, more or less contracted, with short branches usually in pairs bearing spikelets nearly to the bases. The *spikelets* are crowded, 4 to 6 mm (3/16 to 1/4 in) long, with 3 to 6 florets. The *glumes* are shorter than the lowest floret and awnless. The awnless *lemmas* have little or no webbing at their bases.

13. SQUIRREL-TAIL GRASS (*Hordeum jubatum*), also called foxtail barley. Fig. 10. At blooming time, June to early August, this grass can often be spotted at a distance by the patches of shining, bright yellow-green, plume-like spikes. It is a low biennial or perennial grass 30 to 60 mm (1 to 2 ft) tall. The *blades* are narrow, 2 to 5 mm (1/16 to 3/16 in) wide. The *inflorescence* is a nodding spike with awns so long and spread out that at a distance it resembles a panicle. The *spikelets* are in groups of 3 in 2 rows on the spike. Only one of the three, the middle, has a fertile floret; the other 2 are reduced to 1, 2, or 3 spreading awns. The *glumes* are awnlike, and the *lemmas* also have long awns. All these *awns* are from 5 to 8 cm (2 to 3 in) long; they are soft, silky, and often pinkish when young but hard and sharp when mature. The ripe spikes can be dangerous if eaten by animals. The ripe spikelets fall from the plant in groups of 3, one fertile and two vestigial. This grass is in the same genus as barley.

14. QUACK GRASS (*Agropyron repens*), also called couch grass, wheat grass, and several other names. Fig. 8. Whether you curse or bless this perennial grass depends on where you find it. An unseen but important character is the long scaly rhizome that can grow downward to 12 in. or more beneath the ground surface, and for a meter (1 yd) or more laterally.

This feature makes it highly valuable as a soil binder in erosion control, but a serious problem in cultivated fields. Anyone who has spent hours dragging the long tough rhizomes out of the garden beds can appreciate the farmer's problem in his cornfields.

Quack grass develops into a tall grass 50 to 100 cm (1½ to 3 ft) in height and blooms in June and July. The *blades* are flat, 6 to 10 mm (1/4 to 3/8 in) wide and often hairy on the upper surface. The *inflorescence* is a slender, erect spike 5 to 15 cm (2 to 6 in) long with numerous *spikelets* oriented broadside against the stem (in contrast to ryegrass in which the spikelets are oriented edgewise to the stem). The spikelets are 10 to 15 mm (3/8 to 9/16 in) long and have 4 to 6 florets. The *glumes* are sharp-pointed and shorter than the spikelet. *Lemmas* are sharp-pointed with awns of variable length, from less than 1 mm to as long as the lemmas.

LATE SUMMER GRASSES

Blooming in late July through early September

15. GREEN FOXTAIL GRASS [*Setaria viridis* (L.) Beauv.]. Fig. 17, also called bristlegrass. An annual grass common in the garden beds, coming up as broad, bright-green shoots late in June and early July, developing into small tufts and blooming in late July and August. The height of the flowering stem varies from 20 to 100 cm (8 in to 3 ft). It is a hardy plant and dwarfed specimens appear on trampled ground and in cracks of sidewalks. The *blades* are fairly long, up to 15 cm (6 in) and are about 10 mm (3/8 in) wide. The *sheaths* tend to be hairy. The *inflorescence* is a panicle but looks like a thick spike, the spikelets having very short stems. The long soft bristles that cover the inflorescence are not awns but long hairs springing in groups of 3, sometimes less, below each spikelet, and are 6 to 10 mm (1/4 to 1/2 in) long. The color is usually green, sometimes purplish. The *spikelets* are about 2.5 mm (1/16 in) long and have one fertile floret with a scale-like sterile floret below it. The *glumes* are very unequal, one being so small as to be scarcely visible. There are no awns. When the seeds are ripe, the spikelets fall, leaving the bristles on the plant.

Similar to green foxtail is yellow foxtail [*S. glauca* (L.) Beauv. formerly *S. lutescens* (Weigel) Hubb.]. This grass is somewhat larger and the inflorescence is yellow. Also there are 5 to 20 bristles below each spikelet.

16. LARGE CRAB GRASS (*Digitaria sanguinalis*), also called finger grass. Fig. 22. The species name is Latin and refers to an herb used in blood staunching (presumably when used as a poultice of crushed leaves and stems).

It is an annual, sending up bright-green shoots in late June, very like foxtail grass, appearing in garden beds, thin places in lawns, and waste places in general. It looks fine in the lawns in July and still makes a good cover in August when it blooms, but dies with the first frost leaving brown and eventually bare patches. It gets the name of "crab grass" from the way it spreads out sideways like a crab as the lower parts of the stems lie on the ground and root at the nodes. On bare fertile ground, such as a vegetable bed or a compost pile, I have measured single plants spreading as much as a meter (1 yard) in diameter. The size of the plant varies greatly with the location, the blooming stems being from 30 to 60 cm (1 to 2 ft) long, sometimes shorter when found at the edge of sidewalks or growing through cracks in pavement, like foxtail grass. Short-stemmed inflorescences, parallel to the ground, appear on lawn plants and those growing on trodden ground.

The somewhat hairy *blades* are 4 to 10 cm (1½ to 4 in) long and 5 to 20 mm (3/16 to 3/8 in) wide. The *inflorescence* is arranged in clusters of long, thin spike-like racemes, 3 to 6 in each of 1 to 3 whorls, each raceme being 5 to 15 cm (2 to 6 in) long. The *spikelets* are about 3 mm (1/8 in) long and have one fertile floret with a single sterile one below it resembling a glume. The first *glume* is minute and sometimes missing. The second glume is 1/3 to 1/2 as long as the fertile floret, and the sterile floret is nearly as long as the fertile one. The fertile florets are light-colored—pale-green or more typically, light-gray.

Very similar is smooth or small crab grass, *D. ischaemum.* Its name also means blood-staunching, this time in Greek. It grows in the same kinds of places as large crab grass and resembles it but is smaller. The size of both large and small crab grass species depends to a great degree on growing conditions. Large crab grass has somewhat hairy stems and leaves, and the second glume is no more than 1/2 as long as the light-colored fertile floret. Smooth crab grass has smooth stems and leaves, and the second glume is as long as the fertile floret which is dark-brown or purple.

17. STINK GRASS *(Eragrostis cilianensis,* formerly known as *E. megastachya*), sometimes called strong-scented love grass. Fig. 18. This grass gets its name from its musty odor when fresh. It blooms from late June to October, but principally in August. It is frequently rather low, growing in tufts with the stems tending to spread outward. In favorable situations it can become fairly tall, but it is often found in flat tufts on well-drained sites including roadsides and driveways. The height of the flowering stems varies from 20 to 90 cm (8 in to 3 ft). The *blades* are 3 to 8 mm (1/8 to 5/16 in) wide and are bordered by wart-like glands. The *ligule* is interesting, being a fringe of hairs instead of a membrane. The *inflorescence* is a panicle of alternate branches 5 to 20 cm (2 to 8 in) long, gray-green in color, with many spikelets growing close together. The *spikelets* are decidedly flattened, 5 to 15 mm (3/16 to 9/16 in) long and have 10 to 40 florets. The *glumes* are shorter than the lowest floret.

18. SANDBUR (*Cenchrus longispinus*), also called burgrass. Fig. 23. This annual grass hardly needs mentioning, except that it is not always recognized as a grass. It is usually found in sandy soil where it is often sufficiently common to make going barefoot a painful mistake from July on when the burs form. The plant can be tall but is generally low, the stems tending to spread horizontally forming tufts and patches. The height of the flowering stems varies from 10 to 90 cm (4 in to 3 ft). The *leaf-sheaths* are

rather loose, and the *blades* are 4 to 8 mm (3/16 to 5/16 in) wide. The *inflorescence* is a spike-like raceme 3 to 8 cm (1 to 3 in) long bearing a varying number of spherical burs. These burs are formed by the joining and hardening of a number of bristles encircling the base of the spikelets, the ends forming the prickles of the bur. The *spikelets,* usually 2 within each bur, are about 6 mm (1/4 in) long, and their tips can be seen protruding at the top of the bur. There is one fertile floret in a spikelet. The seeds germinate within the bur.

19. WITCH GRASS (*Panicum capillare*), also called tumbleweed grass and tickle-grass. Fig. 16. The sturdy, upright, plume-like panicle is a noticeable feature. It is partly enclosed by a leaf-sheath while flowering, but as the seeds mature the plume-like panicle expands into a frail-looking·sphere that may sometimes be 30 to 45 cm (1 to 1½ ft) in diameter and often breaks off on a windy day and becomes a "tumbleweed." This is another grass that will produce dwarf plants in unfavorable locations such as trampled ground and along sidewalks.

This annual grows in tufts and has hairy leaves 5 to 20 mm (3/16 to 3/4 in) wide. Like stink grass, the *ligule* is of fine hairs. The height of the flowering stems varies from 20 to 80 cm (8 to 2½ ft). The panicle may comprise 1/3 to 1/2 of the plant's height. At the bases of the lower branches of the panicle are hairy round swellings between the branches and the stem. The *spikelets* are awnless, 2 to 3 mm (1/16 to 1/8 in) long, set on fairly long stems, and have one fertile floret and one sterile, glume-like floret below the fertile one. The first glume is about 1/2 as long as the 2nd, and the sterile floret is about as long as the spikelet.

20. BARNYARD GRASS (*Echinochloa crusgalli*), also known as cocksfoot, although the resemblance to a chicken's foot is less obvious than in orchard grass which is also called cocksfoot; a dark-colored variety once exploited as a forage grass is known as Japanese millet and billion-dollar grass. Fig. 19.

Barnyard grass, an annual, appears quite late in the summer, especially on land that has been recently covered with fresh topsoil or barnyard manure. In these places the plants spring up quickly and luxuriantly and are particularly noticeable for their coarse leaves and stems and the peculiar panicle of thick racemes with green to dark brown spikelets. The height of the flowering stem varies from 10 to 150 cm (4 in to 5 ft) depending on growing conditions. The blades are 5 to 15 mm (3/16 to 9/16 in) wide, and there is no visible *ligule.* The panicle may be from 3 to 25 cm (1 to 10 in) long, and the several branches are racemes densely covered with spikelets. These *spikelets,* about 3 mm (1/8 in) long, bear one fertile floret, below which is a sterile glume-like floret. The first *glume* is about half as long as the spikelet. The second glume and sterile floret are as long as the spikelet and hairy. Not all specimens have *awns.* When present, they are found on the sterile lemmas and vary in size from 3 to 10 mm (1/8 to 3/8 in) giving the racemes a fuzzy appearance.

21. WIRESTEM MUHLY (*Muhlenbergia frondosa*). Fig. 20. The bushy habit of this grass makes it recognizable without the inflorescence. The individual plants are 40 to 100 cm (1 to 3 ft) tall, freely branching, and have many short leaves. Since it is a perennial and has long scaly rhizomes, each sending up shoots which root at the nodes, the final result is a plant forming a dense leafy patch. These patches may be found at the edges of fields, under hedges, and along ditches and fences. The inconspicuous flowering stems appear in August.

The *blades* are 5 to 15 cm (2 to 6 in) long and 3 to 8 mm (1/8 to 5/16 in) wide. The short blades often grow toward one side of the stem, giving it the appearance of a flag pole with half a dozen pennants. The *inflorescence* is a more or less contracted panicle 4 to 10 cm (1½ to 4 in) long, and often has the lower parts covered with a leaf-sheath. These panicles appear at the ends of leafy branches. The *spikelets* cover the panicle branches to their bases and are rather small, 2 to 3.3 mm (1/16 to 1/8 in) long, and have only one fertile floret. The *glumes* are unequal, the first short, the second about as long as the usually awnless lemma.

22. NIMBLE-WILL (*Muhlenbergia schreberi*). Fig. 21. This grass looks like a miniature of wirestem muhly, to which it is closely related. It is found in small, bright-green patches of short stems with tiny leaves in lawns and flower beds, at the foot of trees, and under shrubs. It is not usually troublesome as a weed. Because of its small size it is easily overlooked though fairly common. The inflorescence does not appear until quite late in summer.

The plant is low, its inflorescence being only 5 to 18 cm (2 to 7 in) high. It is a perennial, without rhizomes but sometimes rooting at the nodes of spreading stems. The *blades* are short, 2.5 to 5 cm (1 to 2 in) long, and 2 to 4 mm (1/16 to 1/8 in) wide. The inflorescence is a panicle, but the closely appressed branches give it a spike-like appearance. The flowering stems rise well above the patch of leafy stems, but usually have their bases enclosed in a leaf-sheath. The *spikelets* are about 2 mm (1/8 in) long, and the largest *glumes* are less than 0.5 mm (1/64 in) long, almost invisible. There is only one floret in a spikelet. The *lemma* is green or purplish and has an awn 2 to 5 mm (1/16 to 3/16 in) long.

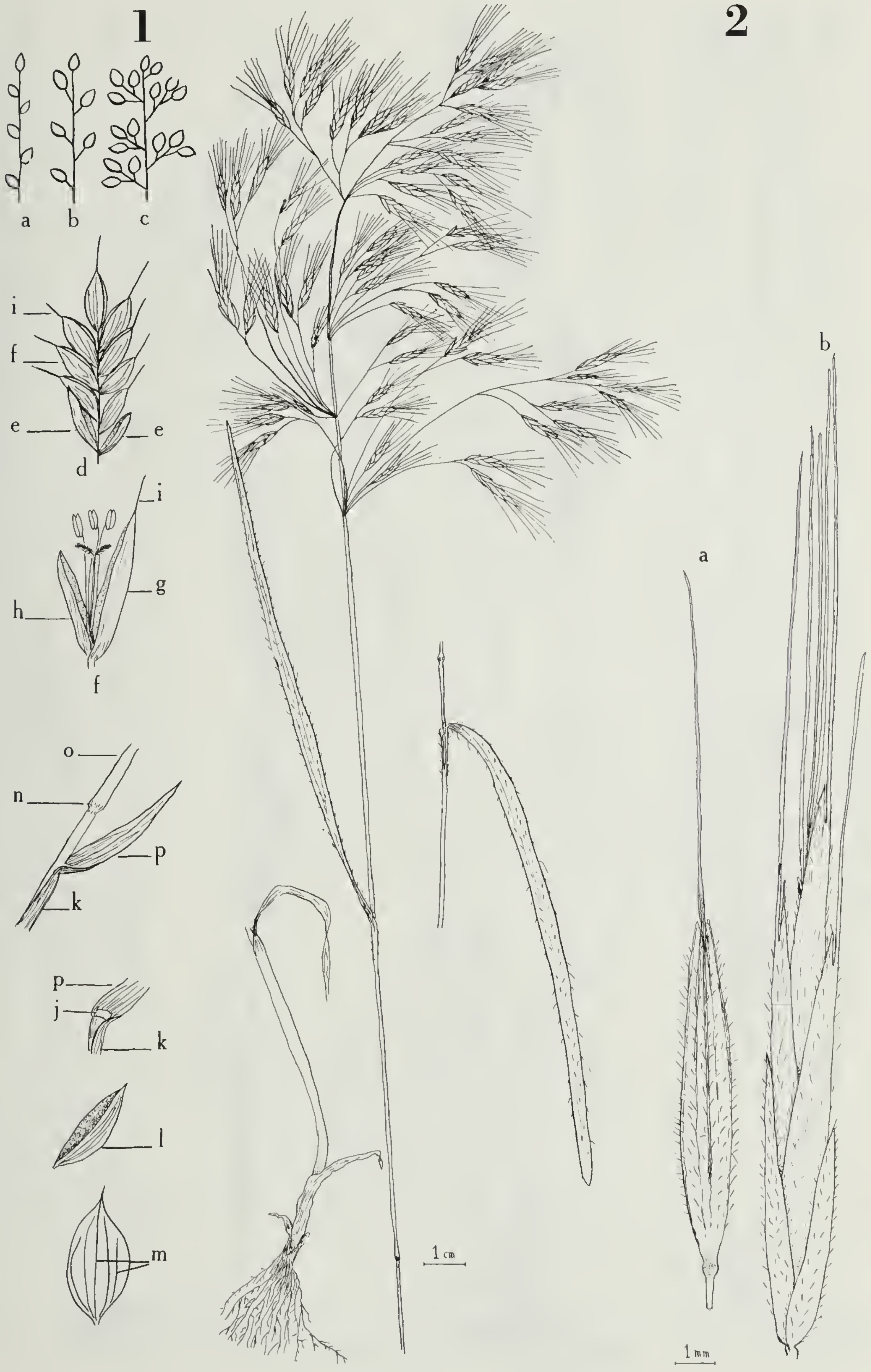
1
a
b
c
i
f
e
e
d
i
g
h
f
o
n
p
k
p
j
k
l
m
1 cm
2
b
a
1 mm

Fig. 1-2. 1. Parts of grass: a. spike; b. raceme; c. panicle; d. spikelet; e. glume; f. floret; g. lemma; h. palea; i. awn; j. ligule; k. sheath; l. keel; m. nerve; n. node; o. culm; p. blade. 2. *Bromus tectorum*: a. floret; b. spikelet.

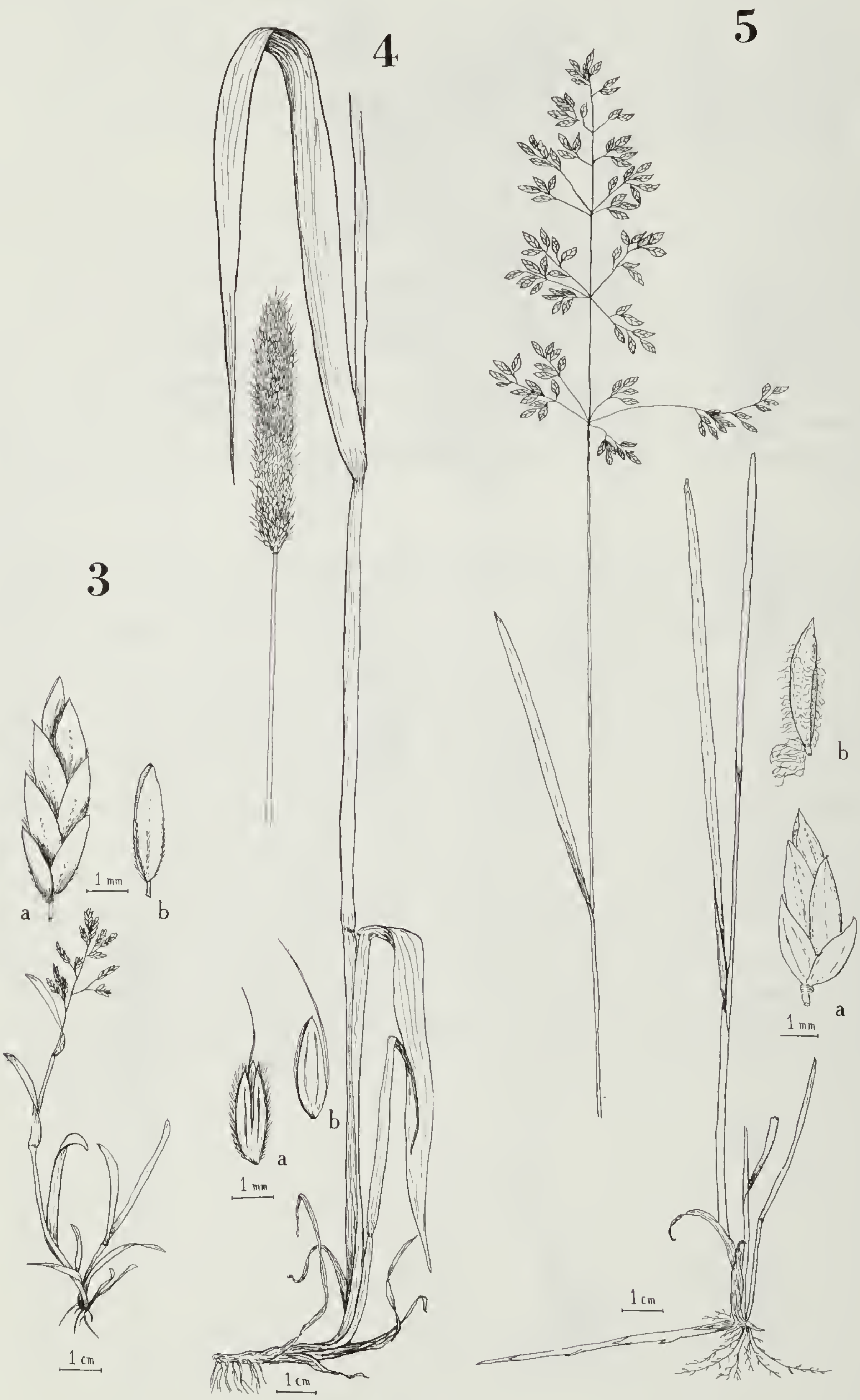
4
5
3
a
b
1 mm
1 cm
b
1 mm
a
1 cm
b
a
1 mm
1 cm

Fig. 3-5. 3. *Poa annua*: a. spikelet; b. floret. 4. *Alopecurus pratensis*: a. spikelet; b. floret. 5. *Poa pratensis*: a. spikelet; b. floret.

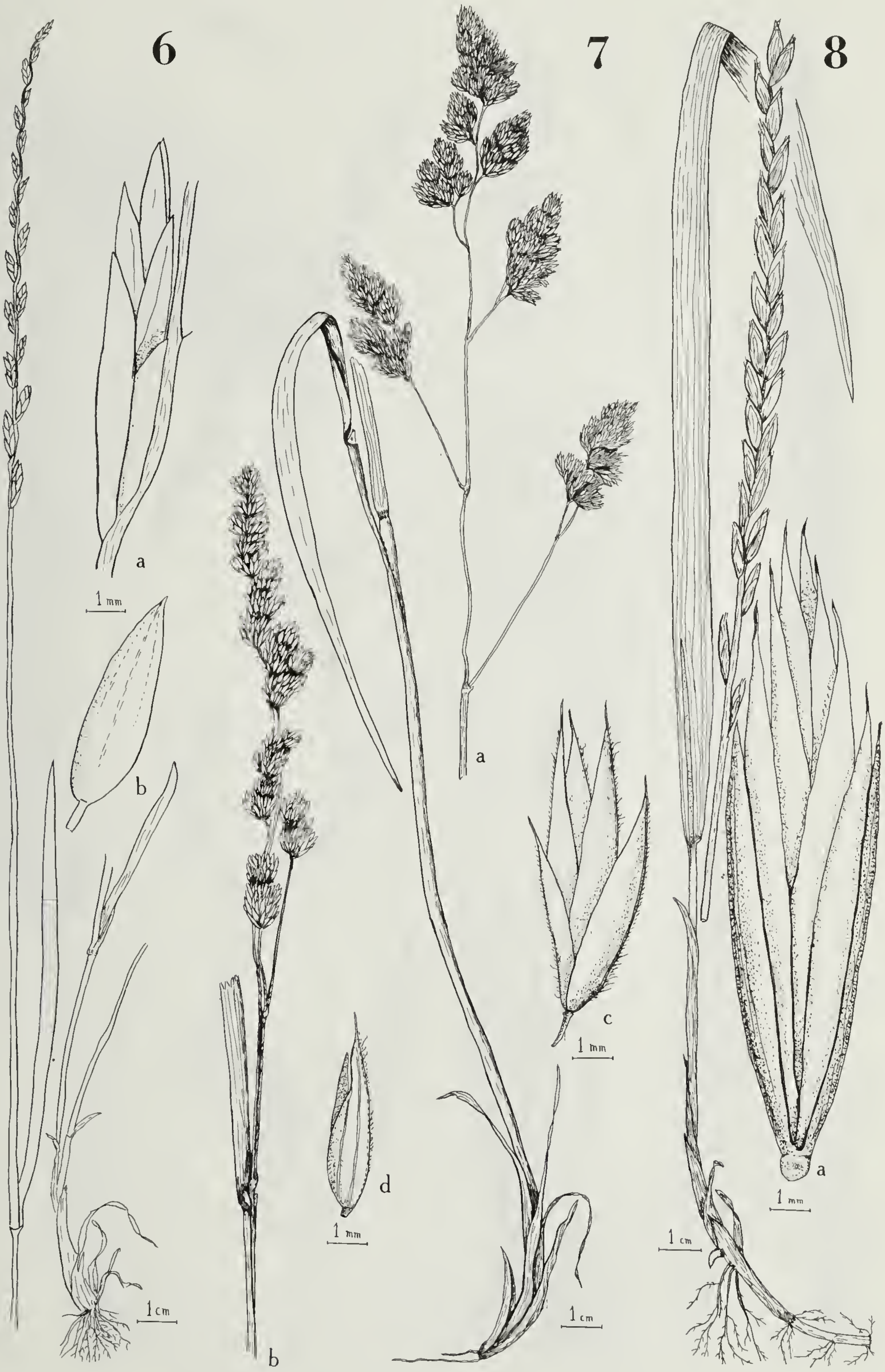
6
a
1 mm
b
1 cm
7
a
b
c
1 mm
d
1 mm
1 cm
8
a
1 mm
1 cm

Fig. 6-8. 6. *Lolium perenne*: a. spikelet; b. floret. 7. *Dactylis glomerata*: a. open panicle; b. closed panicle; c. spikelet; d. floret. 8. *Agropyron repens*: a. spikelet.

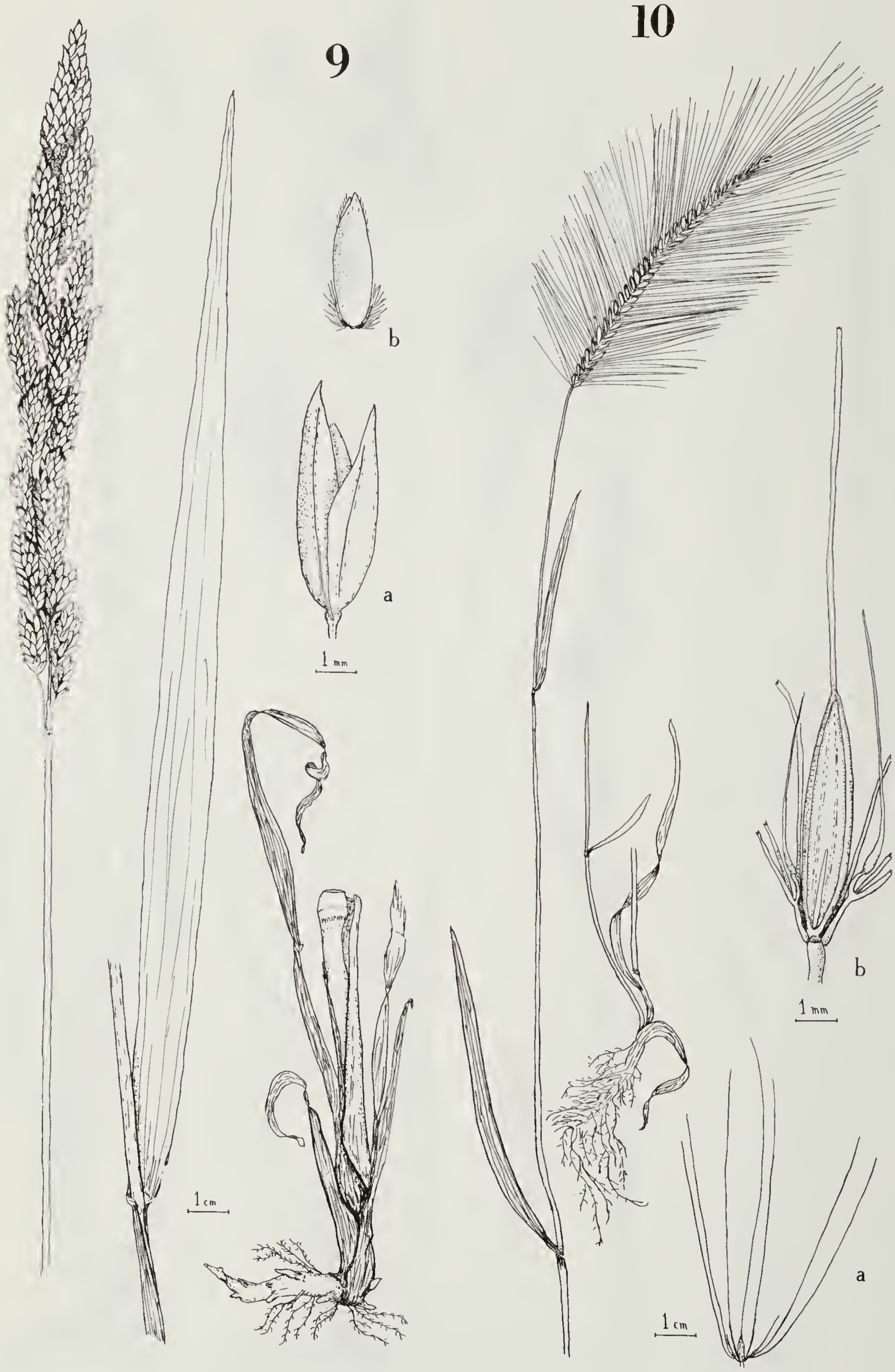
9
b
a
1 mm
1 cm
10
b
1 mm
a
1 cm

Fig. 9-10. 9. *Phalaris arundinacea*: a. spikelet; b. floret. 10. *Hordeum jubatum:* a. spikelet with awns; b. enlarged spikelet.

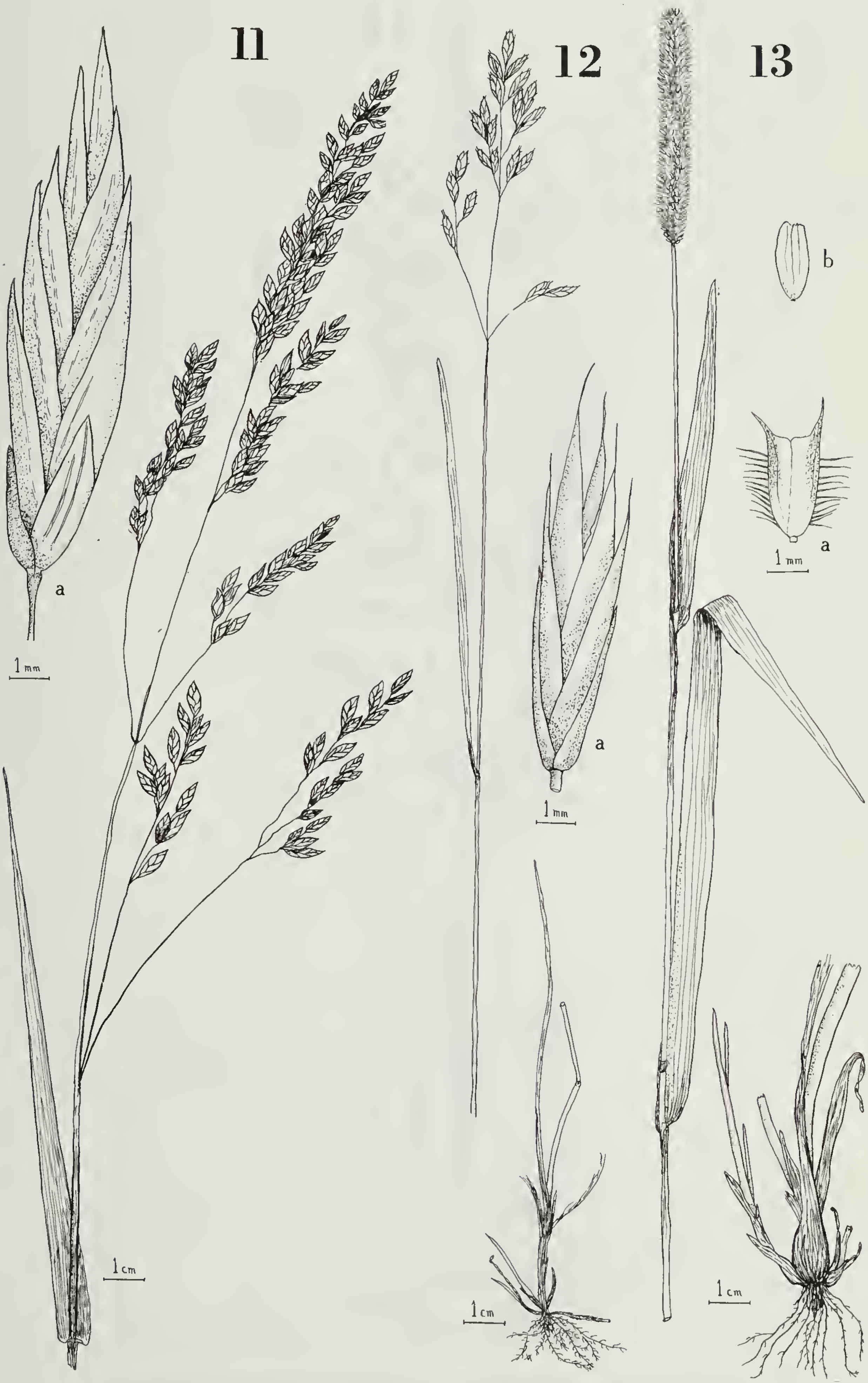
11
a
1 mm
1 cm
12
a
1 mm
1 cm
13
b
a
1 mm
1 cm

Fig. 11-13. 11. *Festuca pratensis:* a. spikelet. 12. *Festuca rubra:* a. spikelet. 13. *Phleum pratense:* a. spikelet; b. floret.

14

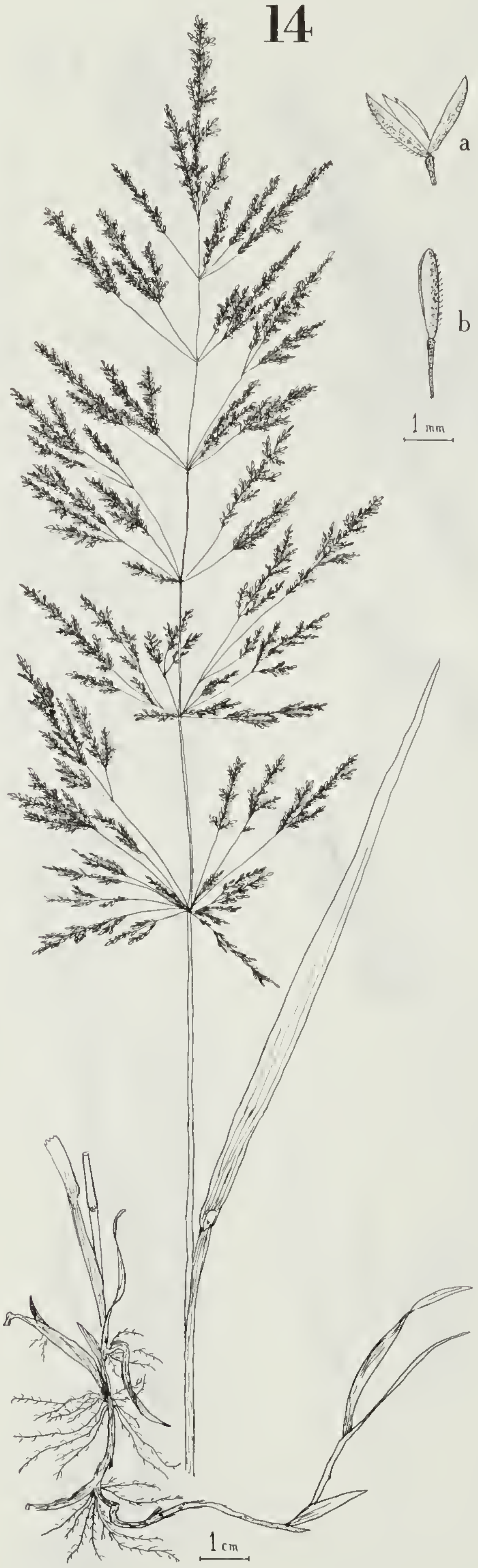

Fig. 14. *Agrostis gigantea:* a. spikelet; b. spikelet with floret.

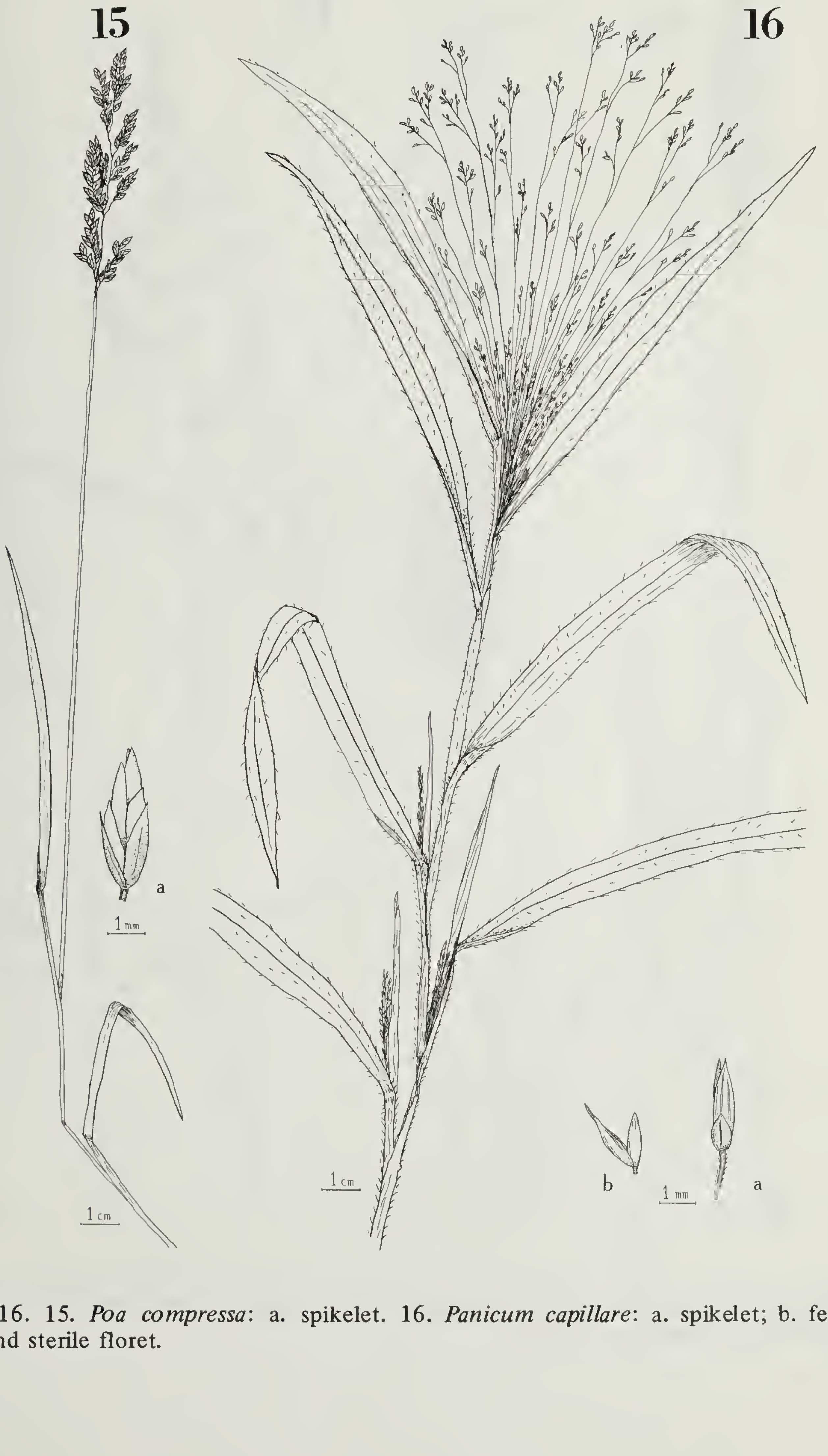
15
a
1 mm
1 cm
16
1 cm
b
1 mm
a

Fig. 15-16. 15. *Poa compressa*: a. spikelet. 16. *Panicum capillare*: a. spikelet; b. fertile floret and sterile floret.

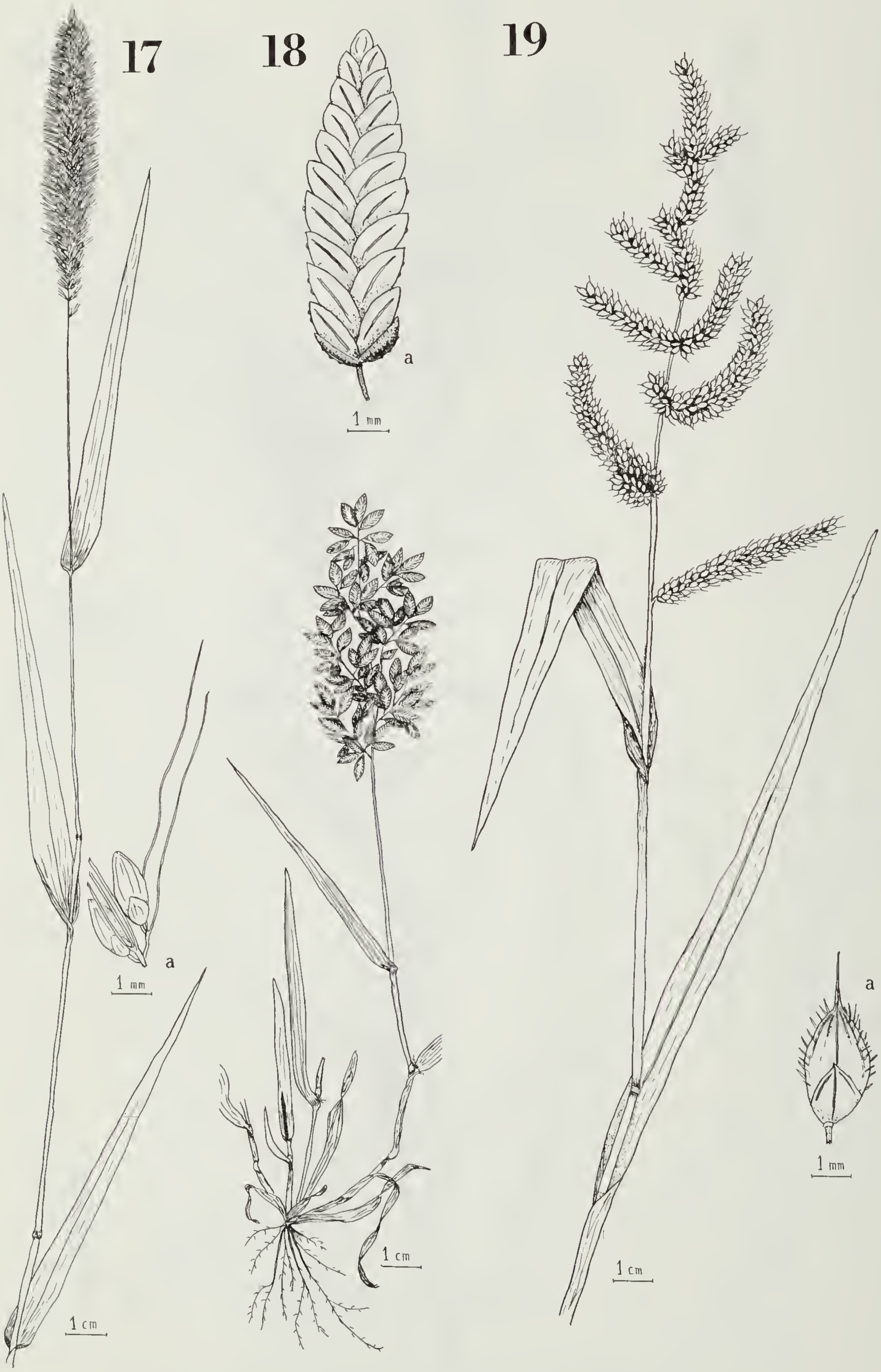
17
18
19
a
1 mm
a
1 mm
a
1 cm
1 mm
1 cm
1 cm

Fig. 17-19. 17. *Setaria viridis*: a. spikelet. 18. *Eragrostis cilianensis*: a. spikelet. 19. *Echinochloa crusgalli*: a. spikelet.

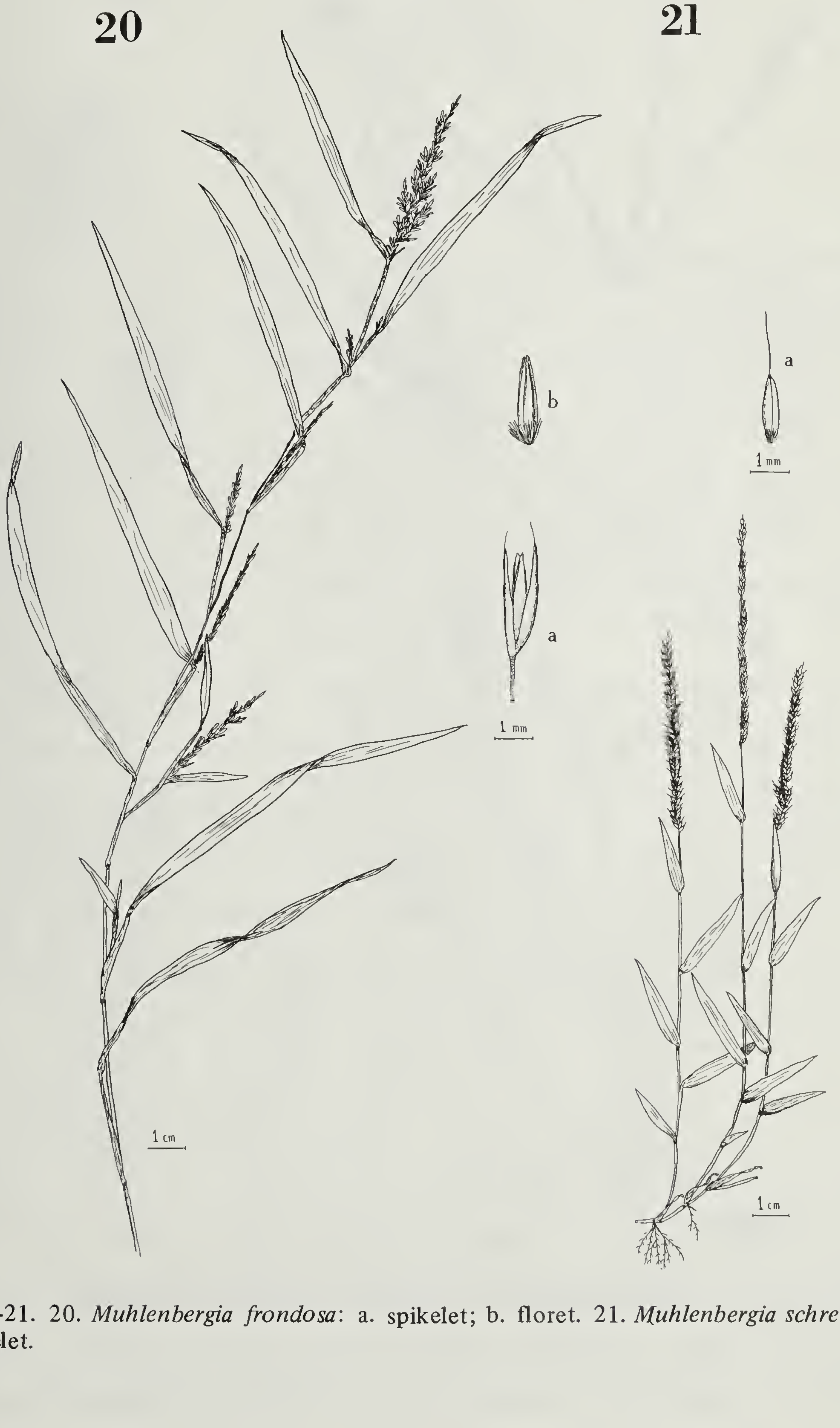
20
21
b
a
1 mm
1 cm
a
1 mm
1 cm

Fig. 20-21. 20. *Muhlenbergia frondosa*: a. spikelet; b. floret. 21. *Muhlenbergia schreberi*: a. spikelet.

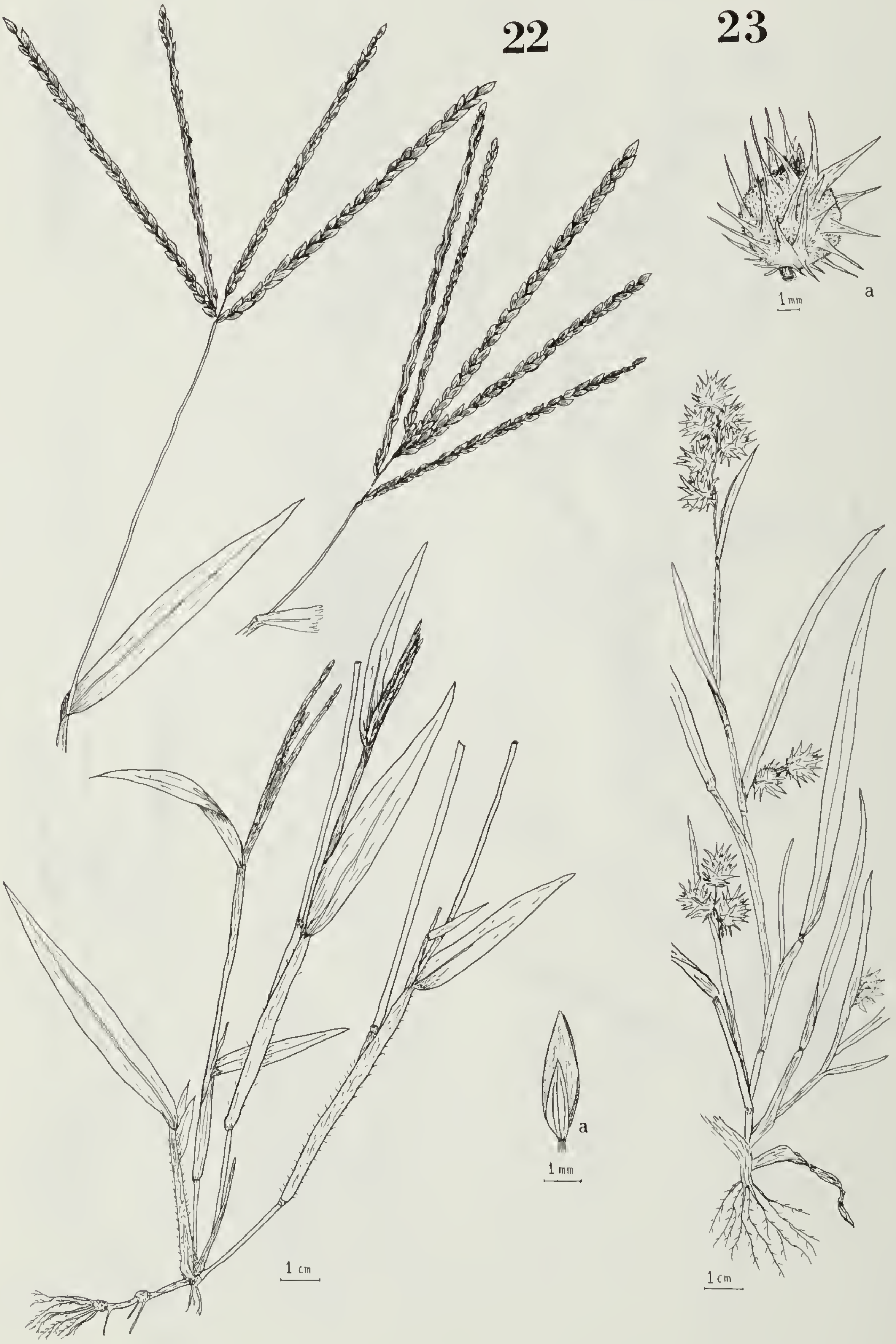
22
23
a
1 mm
a
1 mm
1 cm
1 cm

Fig. 22-23. 22. *Digitaria sanguinalis*: a. spikelet. 23. *Cenchrus longispinus*: a. bur with spikelets.

DALIBARDA REPENS CONFIRMED IN MICHIGAN

Peter B Gorton
Biology Department
Central Michigan University
Mount Pleasant, Michigan 48859

Daniel and Karyn Townsend
1114 West Main Street
Midland, Michigan 48640

Dalibarda repens L. (Dewdrop) has been reported in Michigan floral lists since 1861, but only one herbarium record was known from Michigan until we recently collected specimens in the northern Lower Peninsula. Gleason (1952) gave the range of this woodland species as Nova Scotia to Minnesota, south to New Jersey and Ohio. In the University of Michigan herbarium are specimens only from New York, New Hampshire, and Vermont. *Dalibarda* is known from Michigan only from Bellaire, Antrim County. In 1894, O. E. Close collected two specimens there but did not give a precise location or a description of the habitat. His specimens are filed in the Michigan State herbarium as *Rubus. Dalibarda repens,* a member of the Rosaceae, is a low, perennial herb with slender, creeping stems and simple, cordate leaves; it bears solitary, long-peduncled, white flowers from June to September. Without flowers, it looks similar to a woodland violet.

Dalibarda repens was reported from Ann Arbor, Michigan, on the authority of Miss Mary Clark, in Winchell's list of 1861, and Coleman listed it in his report on the flora of southern Michigan in 1873. Thus, the repetitive listing of this monotypic genus was originated: Miss Clark's collection was cited in Miss Allmendinger's 1876 list of plants of Ann Arbor, in Walpole's 1974 flora of Washtenaw County, and in lists for the state by Wheeler & Smith (1881), Beal & Wheeler (1891), and Beal (1904). The latter three also credited it to Macomb County on the authority of Dennis Cooley. Coulter (1904) reported it from Emmet County and Gates (1912) from the Douglas Lake region, presumably in Cheyboygan County ("found by Mr. Loew in 1910"). Gates & Ehlers (1925) did not include it in their later report on the Douglas Lake flora, apparently realizing that the record was doubtful or mistaken (E. G. Voss, personal communication).

A specimen was collected by Peter Gorton on August 29, 1975 in Sec. 14, T27N, R3W of Crawford County, Michigan, in a moist habitat near the Au Sable River. The overstory was characterized by White Pine (*Pinus strobus*), Balsam Fir (*Abies balsamea*), Red Maple (*Acer rubrum*), Black Spruce (*Picea mariana*), and Paper Birch (*Betula papyrifera*). Plant associates in the vicinity of *D. repens* included Goldthread (*Coptis trifolia*), Trailing Arbutus (*Epigaea repens*), Bunchberry (*Cornus canadensis*), Partridgeberry (*Mitchella repens*), Bracken Fern (*Pteridium aquilinum*), Wild Lily of the Valley (*Maianthemum canadense*), and species of *Lycopodium, Vaccinium, Solidago, Goodyera,* and *Pyrola.* A large population was found in a moist, wooded area adjacent to the river, except in a Speckled Alder (*Alnus rugosa*) community.

Three additional specimens were collected in section 11, T27N, R3W of Crawford County by Daniel Townsend on August 8, 1976 in a low, wooded area characterized by an overstory of virgin White Pine (*Pinus strobus*) and Red Pine (*Pinus resinosa*). The understory consisted of Balsam Fir (*Abies balsamea*), Red Maple (*Acer rubrum*), and Paper Birch (*Betula papyrifera*). Companion plants included the same species found in the previous population, with the exception of *Solidago* and *Pyrola*. Also found in this habitat were Clintonia (*Clintonia borealis*), Wintergreen (*Gaultheria procumbens*), Twinflower (*Linnaea borealis*), Starflower (*Trientalis borealis*), and *Aster*. Our specimens, to the best of our knowledge, are the first to provide specific locations and habitats for the species in Michigan.

Dalibarda repens may well be regarded as an endangered or threatened species in Michigan, and further attempts to verify its occurrence in the state should be carried forth.

Voucher specimens are located at the herbaria of Central Michigan University, Cranbrook Institute, and the University of Michigan. We thank Dr. Daniel Wujek and Mr. Fred Case for contributing to this publication and Dr. Edward G. Voss for confirming our identification and for advice and information.

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STUDIES ON MICHIGAN CHRYSOPHYCEAE. IV

Daniel E. Wujek, Michael Gretz, and Mildred G. Wujek
Department of Biology
Central Michigan University, Mt. Pleasant, 48859

On the basis of electron microscopic studies, four Chrysophyceae are reported as new to Michigan and to the continental United States. One of them, *Chrysosphaerella coronacircumspina,* is described as new. This paper is a fourth of a series on chrysophycean algae of Michigan. Previous papers (Wujek & Hamilton, 1972, 1973; Wujek et al., 1975) have described many of the localities and habitats. One new collecting site is included in the present report: plankton tows were taken from Lake Fenton, Fenton Twp. (Sec. 14), Genesee Co., during October, 1975, and August, 1976. Collecting methods and other locations mentioned in this paper have been described in the papers cited above.

Mallomonas elongata Reverdin (Fig. 1-2). Occurrence of *M. elongata* as verified by electron microscopy has been reported from Alaska (Asmund & Takahashi, 1969), Denmark and Italy (Asmund, 1959), and South America (Thomasson, 1963). It has been observed in a variety of habitats ranging from oligotrophic to dystrophic (Asmund & Takahashi, 1969). We observed it in Lake Geneserath on July 28, 1976. Water temperature at the time was 26°C, expanding the temperature range noted by Asmund & Takahashi (1969) of 1.7-18°C; pH of the sampling site was 8.6.

Synura spinosa f. *mollispina* Peterson & Hansen (Fig. 3). Specimens from Lake Fenton provide a third record of a taxon reported previously from Denmark (Peterson & Hansen, 1956) and Alaska (Asmund, 1968).

Chrysosphaerella coronacircumspina Wujek & Kristiansen sp. nov. (Fig. 4-7).[1] The genus *Chrysosphaerella* was recently reviewed by Asmund (1973), who established that at most three species, all colonial, were known. All three have been observed in Michigan and in all probability, only two are really taxonomically legitimate (see Wujek & Hamilton, 1973 for discussion). In the same publication as Asmund's review, Birch-Anderson (1973) described what he believed to be a fourth, though unicellular member of the genus.

During an investigation of nannoplankton on Lake Geneserath (on Beaver Island, Charlevoix Co.), a new species of *Chrysosphaerella* was ob-

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[1] *Chrysosphaerella coronacircumspina* Wujek et Kristiansen sp. nov. Cellulae coloratae motiles, plerumque sphaericae, diametro 9-12 µm. Flagella duo, inaequalia; unum 2-3-plo longius quam diametrum cellulae, seriebus duobus oppositis mastigonematum instructum; flagellum alterum laeve, 1/3-1/2 diametrim cellulae. Corpus cellulae squamis numerosis tectis. Squamae 2-3 µm longae, 0.7-1.0 µm latae, crenata margine leviter elevata in centrali. Setae 7-20 µm longa, basi duobus discis coalescentibus, discus superus coronum elevatum formans in infero, visa ab infimo praebens interiorem marginei sinuatam, distale furcata. Cystae non visae. Planta in lacu Geneserath, Michigan, inventa. Typus speciei in Fig. 6 depictus.

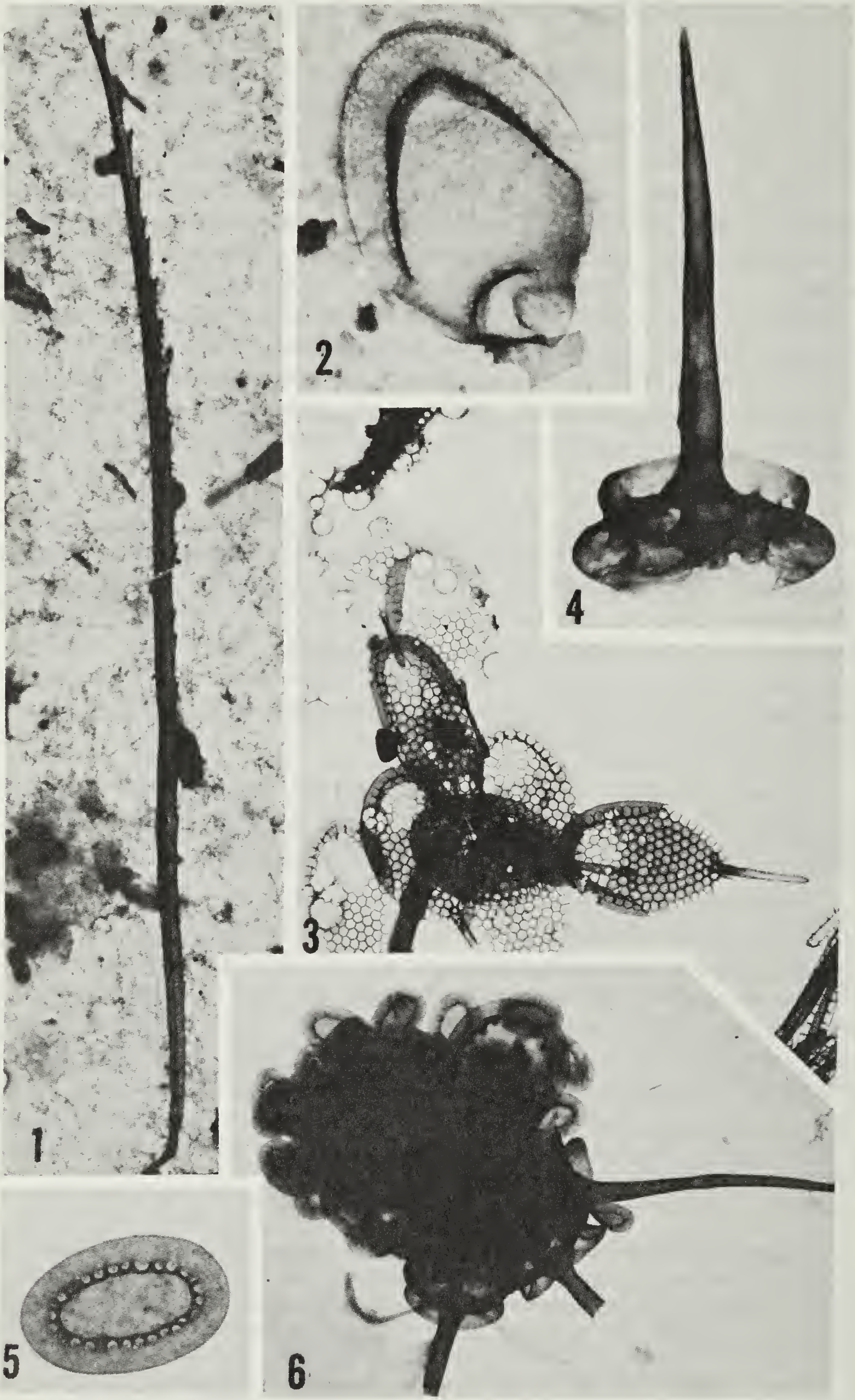


Fig. 1-2. *Mallomonas elongata.* 1. Bristle, ×3200. 2. Scales, ×6800. Fig. 3. *Synura spinosa* f. *mollispina,* ×4500. Fig. 4-6. *Chrysosphaerella coronacircumspina.* Fig. 4. Bristle, ×8100. Fig. 5. Scale, ×12,500. Fig. 6. Whole mount, ×3900.

served. This species, *C. coronacircumspina,* occurred in samples collected during June, 1971 and July, 1976 both as intact cells and as isolated scales and bristles. The water temperature during the July collections was 27°C and the pH 8.6.

Only a very few cells have been observed with the light microscope, and the description is, therefore, mainly based on electron microscopy. Only single cells were observed. They are spherical to slightly elongated and contain what appears to be one deeply lobed chloroplast or possibly two separate plastids. A flimmer 2-3 times the length of the body and a whiplash flagellum 1/3-1/2 the body length are present. The bristles (spines) are clearly visible with the light microscope, but the scales can be seen only with great difficulty. Cells are 9-12 μm in diameter. From two to nine bristles per specimen were observed on individuals examined.

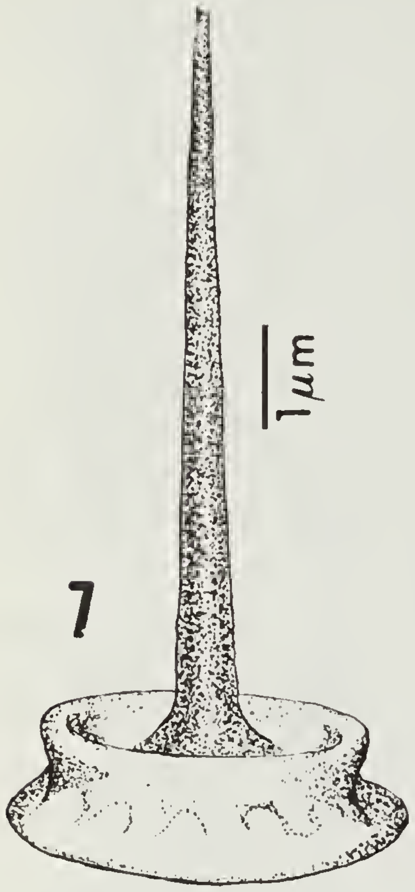
The elliptical scales show little variation in appearance. Near the central part is a raised, beaded rim. At first glance the scale appears to belong to *Chrysosphaerella brevispina,* but the difference in size is obvious [see figure 2C of Kristiansen's (1969) paper where scales of *Chrysosphaerella multispina* and *C. coronacircumspina* are lying side by side]. Scales are 2-3 μm long and 0.7 to 1.7 μm wide.

The bristles are a main character of the genus, as noted by Birch-Andersen (1973). He described *C. salina* as having a bristle resembling the Eiffel tower and unlike those of the other two species examined with the electron microscope. The *Chrysosphaerella coronacircumspina* bristle represents a third type. The proximal part is quite constant in characteristics. It has been reconstructed in Figure 7. The base is composed of two discs as in the other four species; however, the two discs are coalesced with a raised crown on the lower. In the other four species, the discs are separate. Bristles of *C. coronacircumspina* range in size from 7-20 μm long. The lower disc of the bristles is 3.5-4 μm in diameter. The distal end of each bristle is furcate, and the proximal end when viewed from the bottom possesses a wavy or undulate inner margin. On the side of the base of each bristle where it joins the disc a large hole is located. The specific epithet makes reference to a spine with its base possessing a rim or crown.

The photograph, Figure 6, is designated as the type. Type material has been deposited with the herbarium, Central Michigan University.

Electron micrographs published previously show scales of *C. coronacircumspina.* Kristiansen (1969) in his Lake Sträken (Sweden) paper pictured one (in his Fig. 2) without drawing attention to it; later (1975, Fig. 31) he incorrectly called the species *Spiniferomonas trioralis* from material collected in Kootenay Lake, Alberta.

Epipyxis kenaiensis Hilliard & Asmund (Fig. 8). This species was found in Coldwater Lake during the summer of 1974, where it was attached to *Fragilaria crotonesis* colonies, either solitary or in small colonies. It had previously been found only in its type locality, attached to *Dinobryon divergens* and *Asterionella formosa* colonies in Gene Lake, Alaska (Hilliard & Asmund, 1963). Although both those species were present in Coldwater Lake,



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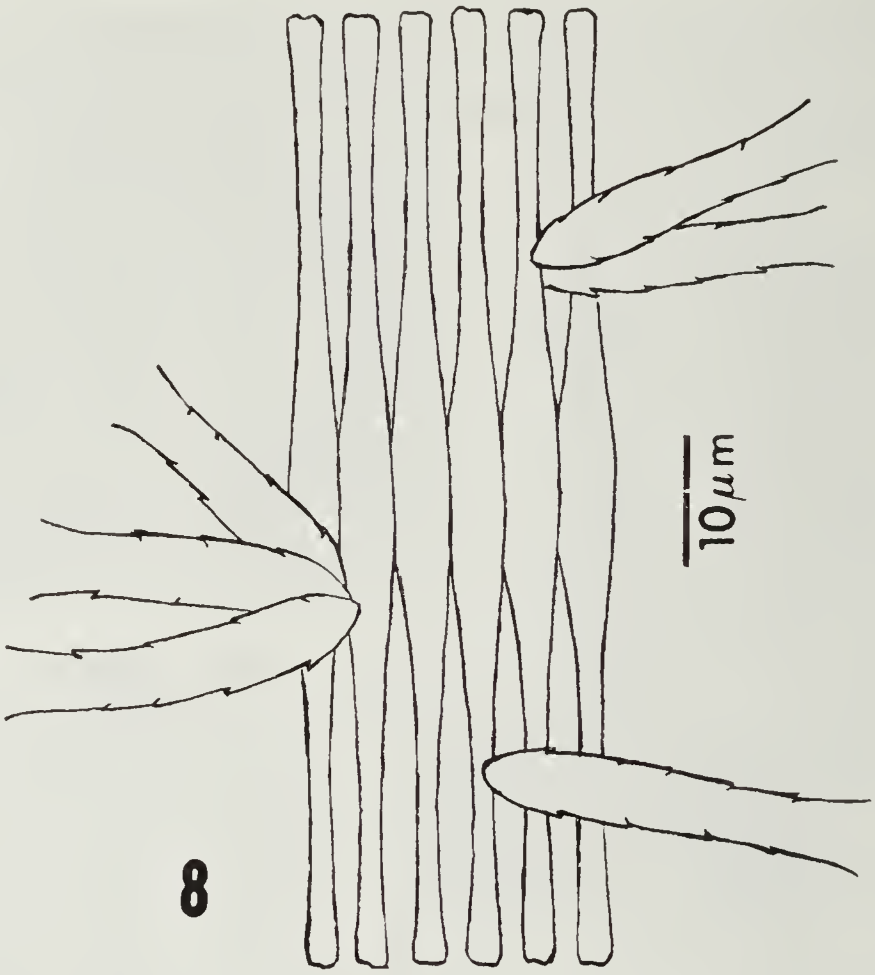

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Fig. 7. Schematic drawing of a bristle which covers the surface of the cells of *Chrysophaerella coronacircumspina.* Fig. 8. *Epipyxis kenaiensis* attached to *Fragilaria.*

E. kenaiensis was not found on them. It was observed from June 28 to August 9, 1974, with a high of 28 cells per milliliter on June 28 (Moore, 1977).

We would like to thank Mr. Robert Pearce for the Lake Fenton samples and Mrs. Pam Moore for the Coldwater Lake samples. Special thanks are due to Miss Berit Asmund for her confirmation of the *Epipyxis.* We also acknowledge Dr. Charles Ebel for assistance in the preparation of the Latin diagnosis. This study was in part funded by the C.M.U. Faculty Research and Creative Endeavors Committee. The second authority of the species is Dr. Jørgen Kristiansen of the Institute of Plant Anatomy and Cytology, Univeristy of Copenhagen.

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NOLANEA VERNA IN NORTH AMERICA

Samuel J. Mazzer
Department of Biological Sciences
Kent State University, Kent, Ohio 44242

Though rather common and widespread in the Great Lakes region, *Nolanea verna* has not previously been recorded for North America. This species, which fruits during the spring morel (*Morchella*) or sponge mushroom season, may be confined in North America to the Great Lakes region. There is no mention of its presence in the southeastern states by Hesler (1967) or from the Pacific Northwest by Largent & Thiers (1972). There is, however, a packet in Peck's herbarium at Albany, containing this species marked "*Entoloma clypeatum* (L.) Fr., Lansingburg, Rens. Co. [=Rensselaer County, New York], *C. H. Peck,* May 7," with the additional notation: "Small form = (*E. strictius irregulare* Pk.)." Also handwritten on the packet are the words "*Entoloma strictius vernale*"! From this it is apparent that Peck had in fact seen the species and recognized its early spring occurrence. His varietal name "vernale" was never published, however, and remains a herbarium name only.

Most closely allied to the species clustered around *Nolanea sericea* (Bull. ex Mérat) P. D. Orton, *N. verna* is, in the Great Lakes area, best characterized by early spring fruiting. All other dark-brown to grayish-brown rhodophylls in the Great Lakes area which have umbonate to conic pilei, incrusted cuticular hyphae, and rather small, isodiametric or only slightly elongated spores fruit later, during the summer or fall. *Nolanea verna* keys easily to *Nolanea* section Cosmeoexonema Largent & Thiers (1972), a group which, in North America at least, may be easily recognized but contains species that are often difficult to separate. This is unfortunate, for in cooler alpine and northern forest habitats fungi of this section often represent a rather significant fraction of the agaric flora.

During the spring of 1966, large numbers of *N. verna* basidiocarps were observed in Barry, Jackson, and Washtenaw Counties, in Michigan. The heaviest fruitings seemed to be associated with plantations of red, scotch, and white pine (*Pinus resinosa, P. sylvestris,* and *P. strobus*) 10-30 years in age. Additional heavy fruitings have been observed in oak-hickory forests and to a lesser degree in mixed mesophytic forests.

My experience with *N. verna* in the Great Lakes region indicates that it is truly vernal (Fig. 2), fruiting from mid-April through early June. This of course means that it will frequently be observed by morel hunters. It is therefore important to note that in Europe *N. verna* is suspected of causing severe gastroenteritis (Pilát & Ušák, 1961). Ayer (1974) reported a case of poisoning caused by ingesting *N. verna*. The patient suffered severe gastroenteritis with associated muscular cramps; a toxic effect on the patient's liver function was suspected, for an elevation of blood cholesterol (to 375 mg %) and blood urea levels (to 66 mg %) was observed. At present gastric lavage and supportive treatment, as indicated, will have to suffice until more is known about the toxin–or toxins–and its physiological effects.

In the following description, color names in quotation marks are from Ridgeway's *Color Standards and Color Nomenclature* (Washington, D.C. 1912).

Nolanea verna (Lund.) comb. nov. Figs. 3-7

Rhodophyllus vernus (Lund.) Romagn., Bull. Soc. Mycol. Fr. 63:195. 1947.
Entoloma vernum Lund., Svensk Bot. Tidsk. 3(2):193. 1937.

Pileus 2-6 cm broad, at first conic-campanulate, often with a distinct papilla, expanding to umbonate or broadly convex but nearly always retaining the central umbo or papilla; margin incurved at first and often exceeding the lamellae, frequently becoming lobed or uneven and broadly undulate at maturity; surface hygrophanous, moist and glabrous, except for the disc, which is sometimes faintly rugulose-striate, at times faintly streaked by innate silvery-gray hyphae in the young stages which fade as the cap matures; color variable, from dark gray-brown to near chocolate-brown or paler in age, from near "Mummy Brown" at first, through "Prout's Brown" to near "Snuff Brown" at maturity, finally fading to an opaque, shiny grayish-tan with a slightly darker disc; these colors are usually darkest in young pilei which have not yet fully expanded and become paler as the cap, which is at first non-striate, becomes translucent-striate at the margin at maturity and then fades to become paler and opaque in age. Context at first moist and nearly concolorous with the surface but hygrophanous and soon fading to whitish-tan with the loss of moisture: odor usually not distinctive, but at times faintly nitrous: taste none or at times faintly farinaceous.

Lamellae 3-8(14) mm broad, subdistant, sinuate or deeply adnexed to nearly free, broadest near the stipe and very rarely costate, with two or occasionally three series of lamellulae; color near, but a little grayer than "Tilleul-Buff" at first, then through "Avellaneous" to near "Wood Brown" at

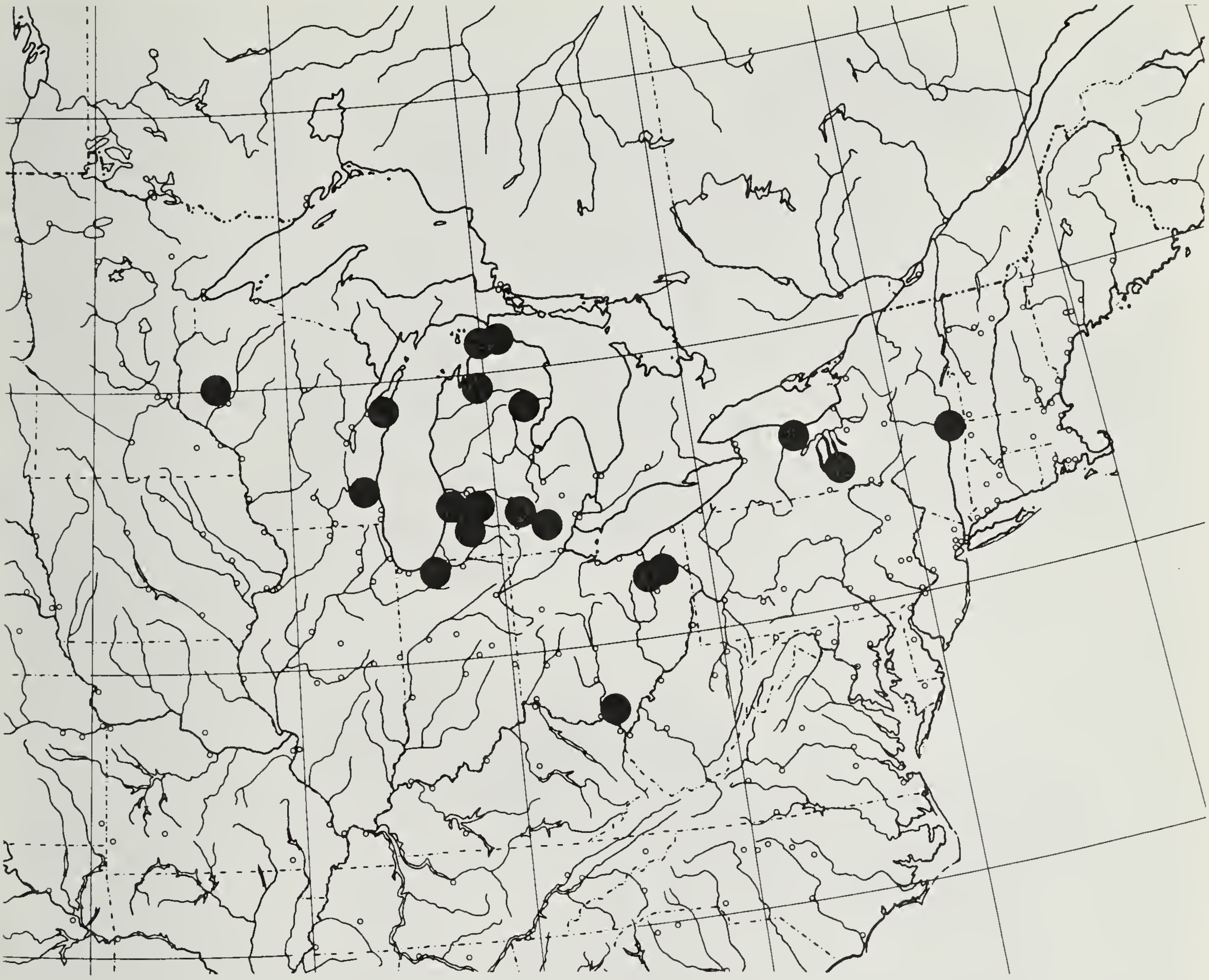
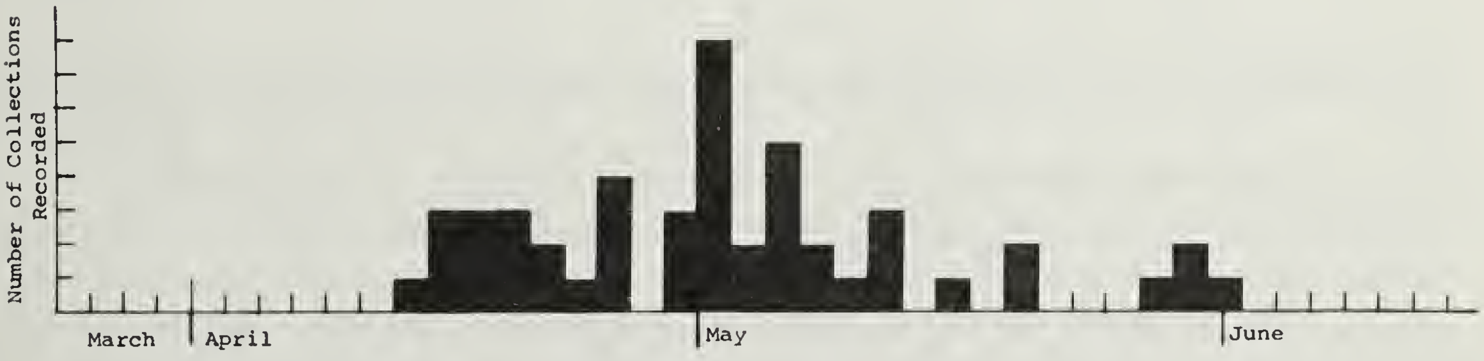
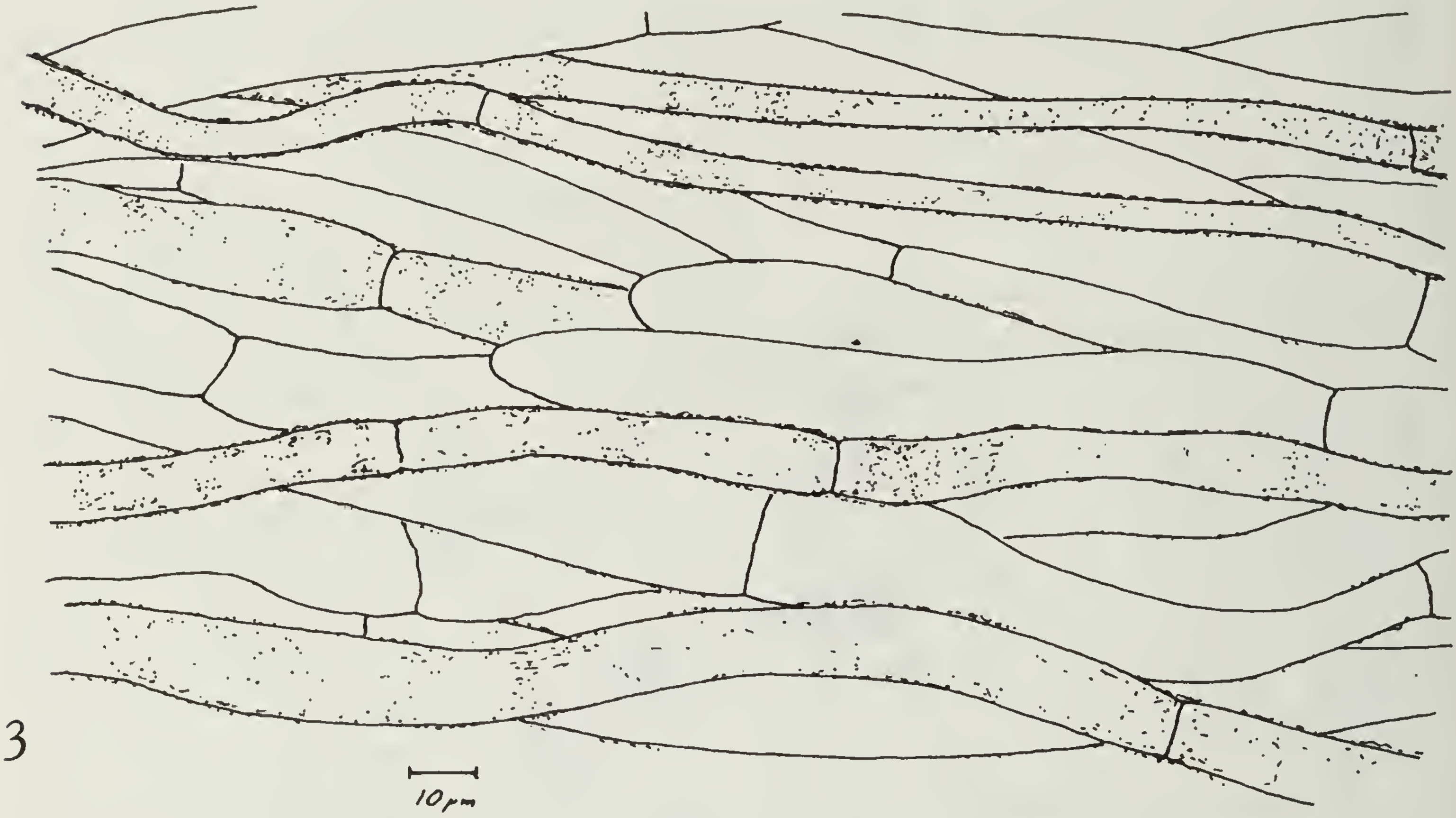


Fig. 1. North American distribution of *Nolanea verna.* (Goode Map Series, copyright University of Chicago; used by permission.)

maturity, becoming paler and occasionally staining brownish along the gill edges in old, faded caps.

Stipe 3-11 cm long, 3-8(10) mm thick, equal or slightly larger downward, at first longitudinally striate from innate silvery fibrils which later fade, usually a bit paler than the pileus, but most frequently near "Snuff Brown" at maturity, scurfy near the apex and with a cottony white mycelium at the base, solid in very young specimens, becoming stuffed or hollow and often





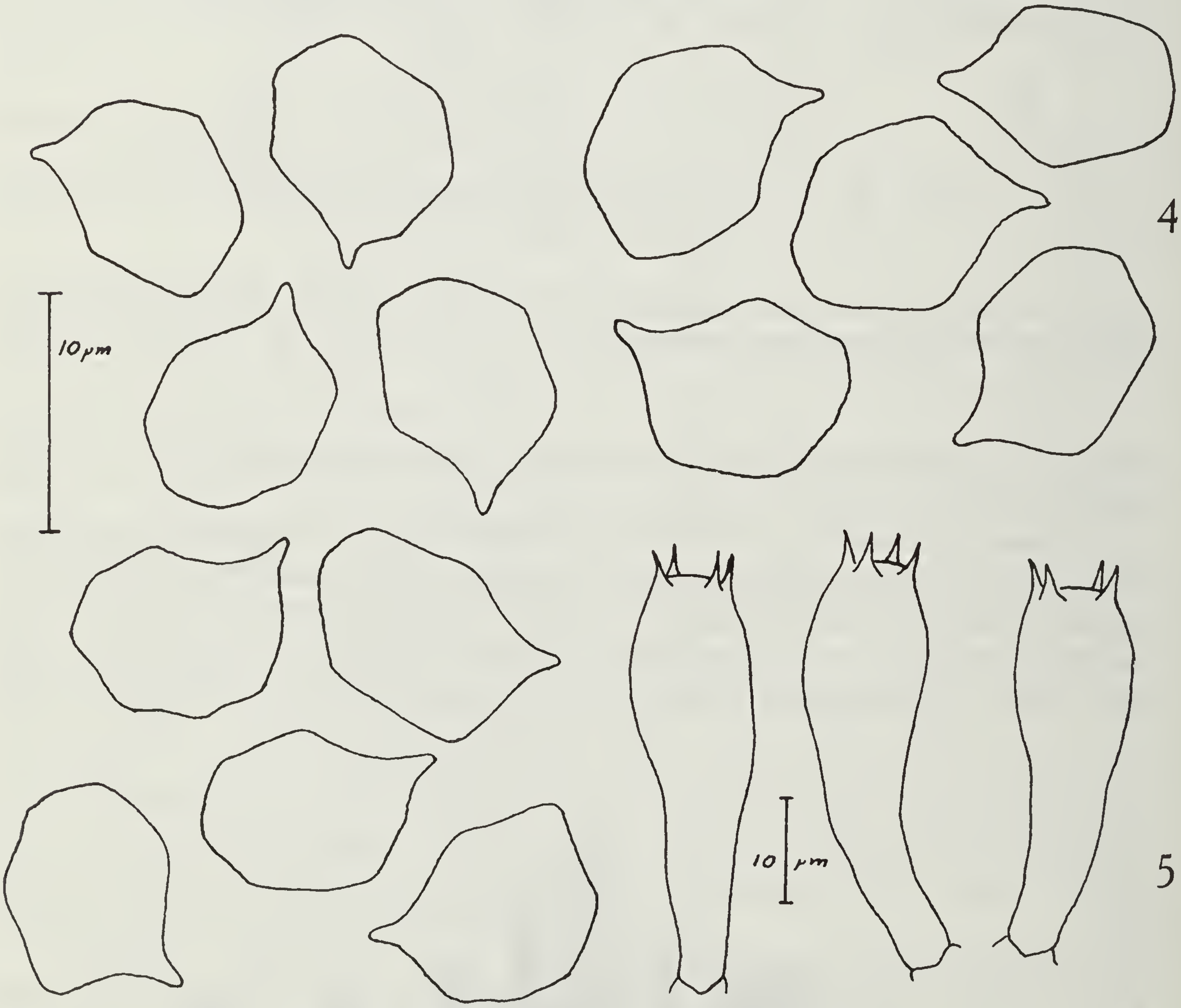

4
10 μm
5
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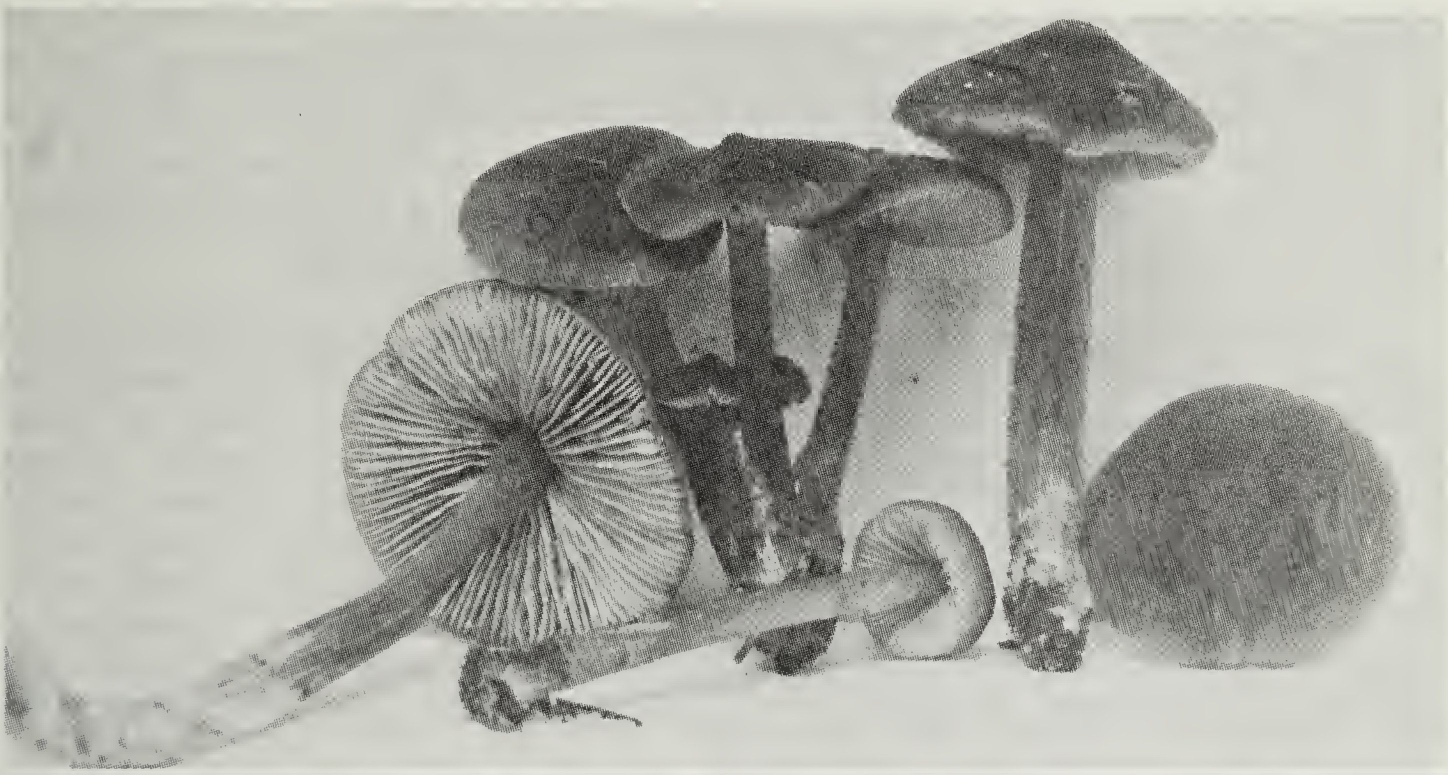
Fig. 3-5. *Nolanea verna.* 3. Pileus surface hyphae. 4. Spores. 5. Basidia.



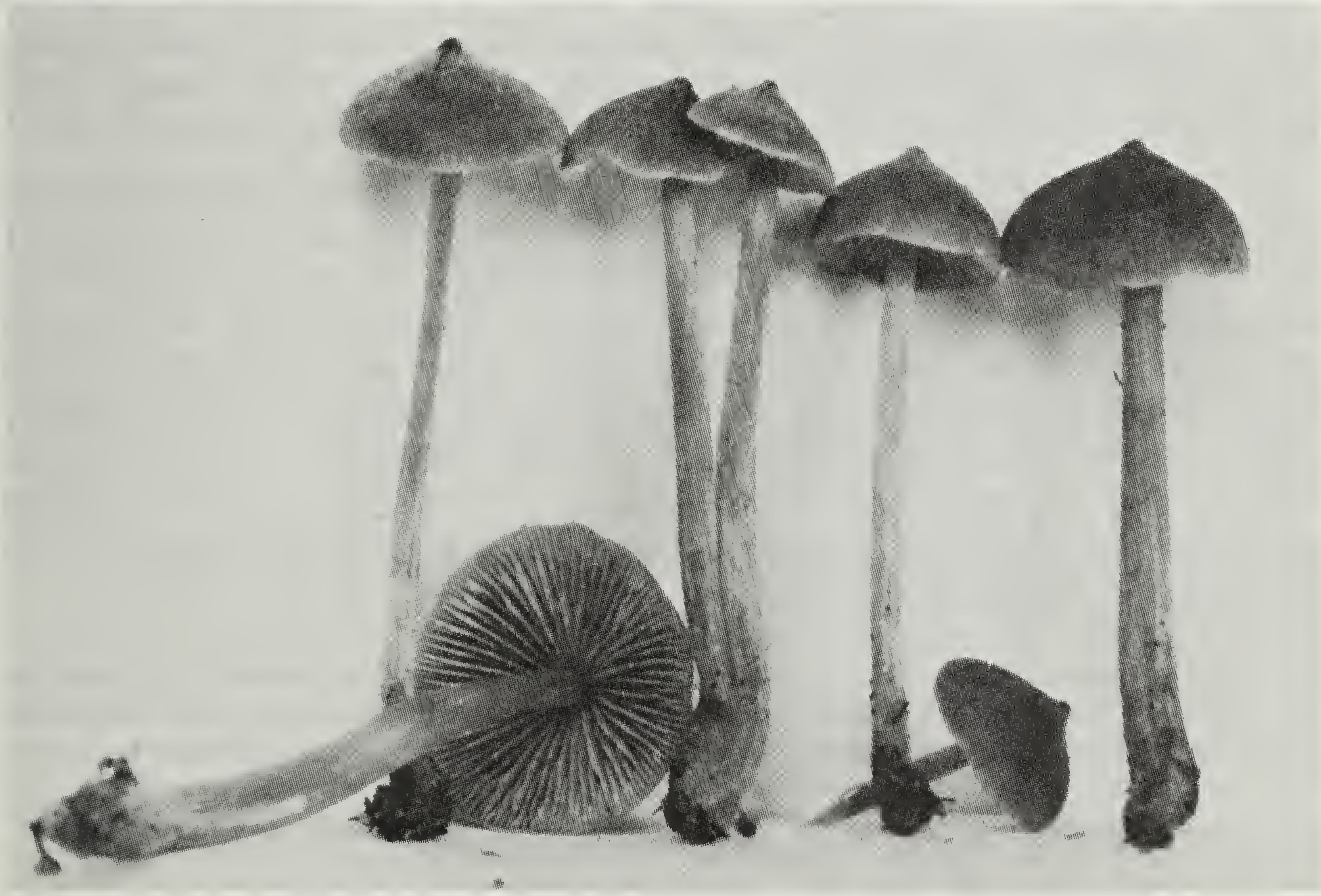


Fig. 6 (above). *Nolanea verna,* about natural size, *Mazzer 3998.* Fig. 7. (below). Same, *Mazzer 3998.* Both photographed by A. H. Smith.

collapsing longitudinally at maturity, central or subcentric in its attachment to the pileus.

Spores 8-11 X 7-8 µm, 6(5-7) sided, pale brownish under the microscope, near "Vinaceous-Cinnamon" in deposit. Basidia 30-45 X 10-15 µm, 4-spored, sterigmata 3-4 µm long, clamps occasionally present at the base of some basidia and on the vegetative hyphae at the base of the stipe. Cheilocystidia and pleurocystidia not observed. Cuticular hyphae appressed, radially arranged, pale brownish to nearly hyaline in color, 5-25 μm thick. The characteristic incrusted pigmentation best developed on the narrower hyphae of the pileus surface. Lamellar trama subparallel, nearly hyaline, the hyphae up to 20 μm thick. Vascular hyphae present to a degree in most of the carpophores studied, consisting of refractive hyphae 4 to 5 μm in diameter, which are rather convoluted and tend to have few, if any, septa.

Collections examined (in the University of Michigan Herbarium unless otherwise indicated): EUROPE. *Sweden.* Fungi Suecici (as *Entoloma vernum* Lund. Upland: Lena parish, close to Vamalsbo, Lundell 8.V.1945. Ballinge parish, "Marsta Skog," H. Smith, 15.V.1945, det. Lundell. Danmark parish, about 200 m SW of Svedden, Lundell 12.V.1945. NORTH AMERICA. *Indiana,* La Porte Co., Shaffer 702; *Michigan,* Allegan Co., Mazzer 4014; Barry Co., Mazzer 4009, 4010, 4011, 4012, 4736; Cheboygan Co., Haard, 1 June 1966, Mazzer 4778, A. H. Smith 63428; Emmet Co., A. H. Smith 51315, 51316, 51317; Jackson Co., Mazzer 2890, 3999, 4000, 6014, 6015; Kalamazoo Co., Mazzer 4036 (KE); Kalkaska Co., La Rue 350; Ogemaw Co., A. H. Smith 49540, 64364; Washtenaw Co., Hoseney, 16 April 1967, 252, 253, 732, 1490, 1492, 2491, 3998, 4005, 4007, 4019, 4738, 4739, 4741, 4762, 5206, 5207, 6017. *New York,* Monroe Co., Vishniac, 4 May 1971; Rensselaer Co., Peck, 7 May [year?] (as *Entoloma clypeatum,* NYS); Tompkins Co., Shaffer 273. *Ohio,* Scioto Co., Miller, 26 April 1975 (KE); Summit Co., Mazzer 7340 (KE); Portage Co., Mazzer 7348 (KE), 8465 (KE). *Wisconsin,* Door Co., Mazzer 6027 (KE); Dunn Co., Mazzer 6376 (KE); Wauksha Co., Mazzer 6365 (KE).

Some minor differences have been observed between North American and European populations. Herink (1956) gives the odor as subspermatic, the taste faintly phenolic, neither of which would apply to the North American material studied. Ayer (1974) gives the odor as gramineous, again, an odor not observed in our material. The differences in odor and taste may indicate compounds unique to collections from mainland Europe or, as is equally likely, differences in sensitivity and subjective analysis between individual investigators. The near perfect agreement of my collections with the original description of Lundell and with authentic material leaves little doubt as to the occurrence of this species in the Great Lakes region.

I am especially thankful for assistance extended to me by Robert L. Shaffer of University of Michigan Herbarium and Stanley J. Smith of New York State Museum. Special thanks are owing to Alexander H. Smith, whose guidance has aided immeasurably in my studies of rhodophylloid agarics.

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FIFTEEN YEARS OF CHANGE IN A SOUTHWEST MICHIGAN HARDWOOD FOREST

Peter E. Zager
Department of Botany
University of Montana, Missoula, 59801

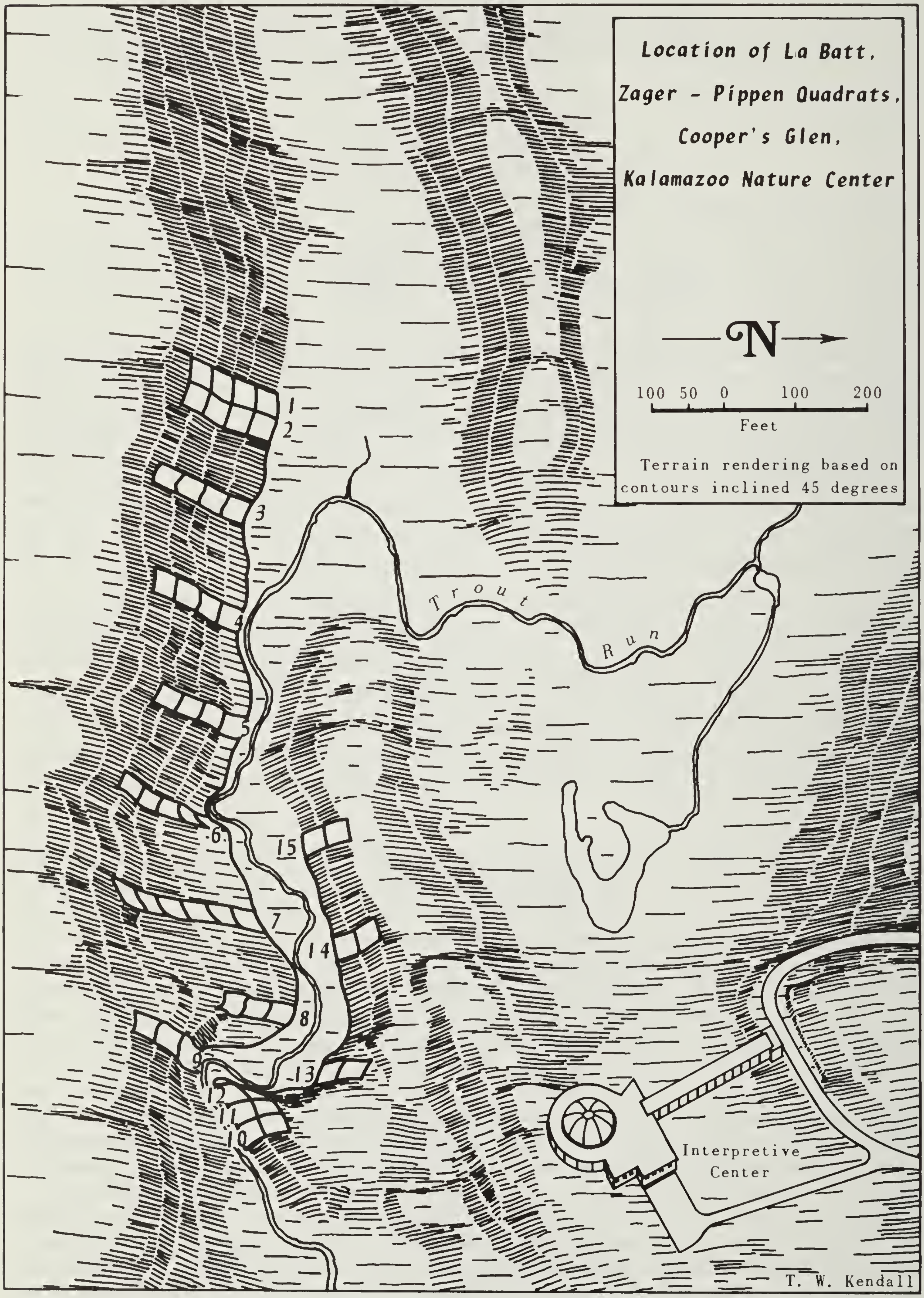
Richard W. Pippen
Department of Biology
Western Michigan University, Kalamazoo, 49008

As ever-expanding suburbia increase pressures on our native plant communities, the need to learn as much as possible about these natural areas becomes more urgent. This paper is an attempt to assess trends in diversity and changes in composition and structure in a hardwood forest in Kalamazoo County, Michigan, over a 15-year period. The area chosen for study is a hardwood forest known as Cooper's Glen, owned and preserved by the Kalamazoo Nature Center for public enjoyment and research. The area lies near the Kalamazoo River and is in the zone designated as the beech-maple association by Kenoyer (1934) on the basis of original land survey data. It is located in the NW ¼, Section 27, T.1S., R.11W. The geology and vegetational history of Cooper's Glen were reviewed by LaBatt (1961). The vegetation apparently has been essentially undisturbed since initial logging operations. Grazing was allowed in open areas adjacent to the stand in the past but is no longer permitted. Cooper's Glen is a "bench mark" stand of sugar maple and beech forest for the North Central States (Benninghoff, personal communications).

In 1960, LaBatt studied the vegetation of Cooper's Glen in an attempt to ascertain the influence of slope on the development of a hardwood forest. His methods and quadrat placement reflect this objective. In our study we repeated LaBatt's methods as exactly as possible and used the same quadrats in an attempt to ascertain any changes that may have occurred over a 15-year period.

A total of 50 quadrats were sampled (Fig. 1). Following the procedures of LaBatt, an 1153-foot baseline following the foot of the north-facing slope (henceforth north slope) was established. Along this baseline nine transects running south were set up. Transects 1 and 2 were 33 feet apart, while transects 2 through 9 were set up at 160 foot intervals. Adjacent square quadrats, 33 feet on a side, were sampled along these transects (the number of quadrats depending on the depth of the woodlot at that point). The south-facing slope (henceforth south slope) was sampled in the same manner. Six transects were established running north from a 567.5 foot baseline which followed the foot of the slope. Transects 10, 11 and 12 were at 33 feet intervals and the remainder at 160 foot intervals. LaBatt offered no explanation for this peculiar layout of sample plots.

Tree species in the quadrats were identified, tallied, and measured for diameter; from these values density, frequency, dominance (basal area per acre), and importance values (DFD) were calculated for the canopy (woody species 5 inches dbh and greater) and midstory (woody species greater than 1 inch dbh but less than 5 inches dbh). Frequency and density for trees taller than 3 feet but less than 1 inch dbh (3′–1″ dbh hereafter) were also calculated. Data on the herbaceous stratum were obtained from ten tosses of a ring, one square foot in area, in each quadrat. Diversity indices were calculated for the various strata using the Shannon-Wiener index (Krebs, 1972).


Location of La Batt,
Zager - Pippen Quadrats,
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Terrain rendering based on contours inclined 45 degrees
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Interpretive Center
T. W. Kendall

Fig. 1. Location of baselines and transects for LaBatt and Zager-Pippen studies at Cooper's Glen.

LaBatt's samplings were made during August. Our sampling of woody plants was done during June, of herbaceous plants in August. Field data for both studies are on file at Western Michigan University with the junior author.

Recent papers dealing with diversity in ecological systems maintain that diversity levels off or declines as the climax stage is reached. Some investigators generalize that diversity is highest midway through secondary succession and decreases thereafter (AuClair & Goff, 1971; Margalef, 1958; Shafi & Yarranton, 1973; Whittaker, 1975). Loucks (1970) believes that diversity reaches a peak at 100-200 years and declines into the climax. Since beech-sugar maple is usually considered the climatic climax forest type of southern Michigan (Braun, 1950; Fowells, 1965), one would expect a decrease in diversity as one enters this stage.

NORTH-SLOPE WOODY PLANTS. The north slope of Cooper's Glen appears to be approaching a pure *Acer saccharum* (Sugar Maple)-*Fagus grandifolia* (American Beech) stand. This is evidenced by the increased density, importance, and dominance of these species and decreases in the same parameters for *Tilia americana* (Basswood), *Ulmus americana* (American Elm), and *Fraxinus americana* (White Ash) during the past 15 years (Table 1).

The large increase in midstory density of *A. saccharum* (Table 3) comes as no surprise since the shade tolerance and reproductive capabilities of this species are well documented (Curtis, 1959; Elliot, 1953; Woolet & Sigler, 1928). This is consistent with the findings of Braun (1950) that *A. saccharum* is often the most abundant understory tree, indicating that this species will become more abundant in the canopy of the ensuing forest. This is also consistent with Brewer's (1976) findings in Warren Woods in Michigan. Ward (1956) found *A. saccharum* has been increasing in density in Wisconsin since 1835, while *F. grandifolia* has been generally decreasing; *Tilia americana* and *U. americana* showed large decreases during his study period.

The canopy composition of the north slope of Cooper's Glen (Table 1) is similar to the upland beech-maple forest of Warren Woods, where *A. saccharum* and *F. grandifolia* make up 90% of the canopy (Braun, 1950). The canopy of the slopes in Hueston's Woods near Oxford, Ohio, is also similar in that *A. saccharum* comprises 64% of the canopy, but it differs in that *F. grandifolia* is the only other canopy species present (Braun, 1950; Adams & Barrett, 1977). Schneider (1966), in a study of a beech-maple forest in southern Michigan, also found *A. saccharum* to be the most abundant tree with *F. grandifolia* next. In this case *F. grandifolia* was not only maintaining itself but increasing in the stand.

The large decrease in *U. americana* in Cooper's Glen can be attributed both to natural successional processes (Elliot, 1953; Schneider, 1966) and to the occurrence of Dutch Elm disease. According to Catana (1967), the fungus entered the state in the late 1950's, which was just prior to LaBatt's sampling. Even though the number of individuals of *U. americana* in Cooper's Glen dropped during the study period, overall density of the forest canopy remained fairly stable (Table 1). This is consistent with Ward's (1956) findings that as the composition of a beech-maple forest changes the canopy should

TABLE 1. Percent composition, density, dominance, and importance of canopy trees on the north-facing slope of Cooper's Glen in 1960 and 1975.

	% Composition		Density (No./A)		Dominance (Sq. in. basal area/A)		Importance (DFD)	
	1960	1975	1960	1975	1960	1975	1960	1975
Acer saccharum	58.2	69.4	47.2	51.3	9124.0	11,903.6	173.3	194.7
Fagus grandifolia	6.3	20.8	5.1	15.4	1601.6	5,111.1	17.2	69.5
Fraxinus americana	2.5	0.4	2.1	1.0	302.7	85.8	9.2	5.1
Fraxinus nigra	1.3	–	1.1	–	411.4	–	6.4	–
Tilia americana	8.9	6.9	7.2	5.1	2432.9	1,678.8	36.3	27.7
Ulmus americana	22.8	1.4	18.5	1.0	1856.0	57.1	51.2	4.0
Total			81.2	73.8				

TABLE 2. Percent composition, density, dominance, and importance of canopy trees on the south-facing slope of Cooper's Glen in 1960 and 1975.

	% Composition		Density (No./A)		Dominance (Sq. in. basal area/A)		Importance (DFD)	
	1960	1975	1960	1975	1960	1975	1960	1975
Acer saccharum	70.4	70.4	69.1	69.1	9142.5	10,791.4	182.1	190.2
Fagus grandifolia	14.8	18.5	14.5	18.2	1982.8	4,217.1	46.0	54.0
Quercus borealis	–	3.7	–	3.6	–	320.3	–	7.0
Tilia americana	14.8	7.4	14.5	7.3	6563.7	5,306.1	71.9	48.2
Total			98.1	98.2				

TABLE 3. Percent composition, density, dominance, and importance of midstory trees on the north-facing slope of Cooper's Glen in 1960 and 1975.

	% Composition		Density (No./A)		Dominance (Sq. in. basal area/A)		Importance (DFD)	
	1960	1975	1960	1975	1960	1975	1960	1975
Acer saccharum	36.8	75.8	36.0	206.2	302.4	691.2	108.2	206.6
Carpinus caroliniana	–	1.1	–	3.1	–	1.6	–	3.1
Fagus grandifolia	3.2	10.6	16.4	28.7	5.5	95.1	24.9	47.1
Fraxinus americana	5.3	–	5.1	–	29.2	–	16.2	–
Hamamelis virginiana	7.4	1.5	7.2	4.1	15.5	7.6	13.8	4.2
Ostrya virginiana	27.4	5.7	26.7	15.4	124.0	35.2	65.6	22.5
Prunus serotina	8.4	–	8.2	–	9.1	–	14.3	–
Tilia americana	3.2	5.3	3.1	14.4	26.0	36.0	11.5	16.8
Ulmus americana	8.4	–	8.2	–	204.8	–	50.9	–
Total			97.6	271.9				

TABLE 4. Percent composition, density, dominance, and importance of midstory trees on the south-facing slope of Cooper's Glen in 1960 and 1975.

	% Composition		Density (No./A)		Dominance (Sq. in. basal area/A)		Importance (DFD)	
	1960	1975	1960	1975	1960	1975	1960	1975
Acer saccharum	5.6	7.5	3.6	14.5	15.6	18.4	36.5	20.8
Asimina triloba	–	18.9	–	36.4	–	54.9	–	39.6
Carpinus caroliniana	–	24.5	–	47.3	–	64.8	–	59.8
Cornus florida	–	7.5	–	14.5	–	22.0	–	18.1
Fagus grandifolia	22.2	20.8	14.5	40.0	41.8	70.9	78.3	73.2
Fraxinus americana	5.6	–	3.6	–	14.2	–	22.2	–
Ostrya virginiana	–	17.0	–	32.7	–	77.6	–	71.5
Prunus serotina	33.3	–	21.8	–	27.7	–	79.6	–
Prunus virginiana	27.8	–	18.2	–	21.9	–	56.6	–
Quercus borealis	–	1.9	–	3.6	–	12.8	–	9.7
Tilia americana	–	1.9	–	3.6	–	6.2	–	7.7
Ulmus americana	5.6	–	3.6	–	21.0	–	26.9	–
Total			87.3	192.6				

TABLE 5. Density (number per acre) of shrubs on the north-facing and south-facing slopes of Cooper's Glen in 1960 and 1975. An asterisk indicates species not determined in 1960. Species identified in 1975 were *Ribes cynosbati, Rubus hispidus* and *Smilax rotundifolia.*

	North-facing slope		South-facing slope	
	1960	1975	1960	1975
Cornus alternifolia	–	2.0	–	–
Cornus florida	2.0	4.0	22.0	61.6
Hamamelis virginiana	13.2	–	–	–
Lindera benzoin	7.2	24.8	10.8	363.6
Rhamnus catharticus	–	–	–	10.8
Ribes sp.*	23.6	1.2	14.4	14.4
Rubus sp.*	2.0	4.0	–	32.4
Sambucus pubens	3.2	–	–	–
Smilax sp.*	13.2	–	7.2	–
Total	64.4	36.0	54.4	482.8

not be markedly different except for a decrease in *U. americana* and a corresponding increase in the relative density of the associated species. Accompanying the increased importance, dominance and density of *A. saccharum* and *F. grandifolia* on the north slope of Cooper's Glen was a decrease in diversity among the canopy and midstory trees (Table 8). Recalculation of the 1975 canopy diversity index to include *U. americana* at its 1960 density indicated that the decline in *U. americana* is only partially responsible for the decreased diversity found in 1975. Therefore this decline

TABLE 6. Density (number per acre) of woody vegetation 3′-1″ dbh on the north-facing and south-facing slopes of Cooper's Glen in 1960 and 1975.

	North-facing slope		South-facing slope	
	1960	1975	1960	1975
Acer negundo	1.2	–	–	–
Acer saccharum	2017.6	4247.2	200.0	3322.6
Asimina triloba	–	–	–	83.6
Carpinus caroliniana	–	10.4	–	98.0
Carya sp.	–	4.0	–	221.6
Fagus grandifolia	57.6	165.1	178.0	600.0
Fraxinus americana	49.2	74.8	40.0	123.6
Ostrya virginiana	28.8	156.8	–	483.6
Prunus serotina	85.2	14.4	10.8	94.4
Prunus virginiana	–	–	228.0	–
Quercus borealis	3.2	9.2	28.8	170.8
Tilia americana	14.4	11.2	14.4	363.6
Ulmus americana	34.0	–	102.0	–
Zanthoxylum americanum	2.0	–	3.6	7.2
Total	2293.2	4693.1	805.6	5569.0

TABLE 7. Density (number per acre) of herbaceous plants and tree seedlings on the north- and south-facing slopes of Cooper's Glen in 1960 and 1975. An asterisk indicates species not determined in 1960. Species identified in 1975 were *Parthenocissus quinquefolia* and *Sanicula canadensis.*

	North-facing slope		South-facing slope	
	1960	1975	1960	1975
Acer saccharum	52,720	19,900	28,936	47,960
Actaea alba	452	–	–	–
Allium tricoccum	672	–	–	–
Anemonella thalictroides	335	–	792	–
Boehmeria cylindrica	–	112	–	–
Caltha palustris	–	224	–	1584
Carex sp.	1788	1900	5944	9156
Carpinus caroliniana	112	–	–	–
Caulophyllum thalictroides	–	112	–	–
Circaea quadrisulcata	672	112	–	–
Desmodium nudiflorum	–	–	–	4360
Erythronium americanum	2128	–	–	–
Euonymus obovatus	–	784	–	6740
Fagus grandifolia	224	112	15,840	396
Fraxinus americana	448	336	–	1188
Fraxinus nigra	112	–	–	–
Galium sp.	112	–	1980	–
Geranium maculatum	–	–	–	792
Grass	–	–	3964	–
Hamamelis virginiana	112	–	–	–
Hepatica acutiloba	6276	10,620	5944	30,520
Hydrophyllum appendiculatum	1452	3800	–	–
Hystrix patula	1564	–	3172	5152

TABLE 7. (Continued)

	North-facing slope		South-facing slope	
	1960	1975	1960	1975
Laportea canadensis	–	1452	–	396
Lindera benzoin	112	112	–	792
Mitella diphylla	–	784	–	6740
Osmorhiza claytoni	12,320	–	17,044	11,496
Ostrya virginiana	–	224	–	396
Parthenocissus sp.*	5072	1452	3172	4360
Phlox divaricata	–	448	–	4360
Phryma leptostachya	336	–	396	–
Podophyllum peltatum	–	–	1188	–
Polygonatum sp.	782	784	–	1584
Prenanthes alba	–	–	–	1584
Prunella vulgaris	–	–	396	–
Prunus serotina	2012	–	2380	1584
Quercus borealis	336	–	3172	–
Ribes sp.	–	784	–	1188
Rubus sp.	–	224	–	–
Sanguinaria canadensis	112	–	–	–
Sanicula sp.*	116	336	396	7136
Smilacina racemosa	680	–	–	–
Smilax rotundifolia	–	–	–	396
Solidaga caesia	–	–	–	3568
Tilia americana	–	–	–	792
Tovara virginiana	1667	–	–	1584
Toxicodendron radicans	448	560	792	3172
Trillium grandiflorum	112	896	396	1584
Ulmus americana	5032	218	4360	–
Viola sp.	13,750	7043	7928	24,970
Total	112,066	53,329	108,194	185,530

in diversity suggests that succession has progressed into a mature beech-maple forest on the north slope studied at Cooper's Glen. This decline in diversity is in agreement with the findings of earlier investigators that diversity peaks midway through secondary succession and declines into the climax. Brewer (1976) also found a general decrease in diversity in an 11-year study of Warren Woods.

A large increase in density of *A. saccharum* in the 3′-1″ dbh category and smaller increases in *Fagus grandifolia, Fraxinus americana, Ostrya virginiana* (Hop-hornbeam), and *Carpinus caroliniana* (Hornbeam) were also noted (Table 6). This seems to indicate that *A. saccharum* will eventually become more abundant, although not an exclusive dominant, in the ensuing forest (Bergman, 1923; Esten, 1932). Brewer (1976) also found a general increase in density among woody plants one foot tall and under one inch dbh in Warren Woods, with *A. saccharum* by far the densest species in this layer.

Diversity among the shrubs also declined during the study period (Table 8). The decrease probably resulted from the relative shade intolerance of the

TABLE 8. Number of species (S) and Shannon-Wiener index of diversity (H′) for the vegetational groups on the north-facing and south-facing slopes of Cooper's Glen in 1960 and 1975. *Canopy trees* (5 in. dbh and greater); *midstory trees* (more than 1 in. dbh, less than 5 in.); *smaller woody plants* (more than 3 ft. tall & less than 1 in. dbh); *shrubs* (non-canopy woody plants); *herbs & woody plant seedlings.*

	North-facing slope		South-facing slope	
	1960	1975	1960	1975
Canopy trees				
S	7	4	4	4
H′	1.2421	.8238	.9381	.8745
Midstory trees				
S	8	6	7	8
H′	1.7046	.8814	1.6632	1.8267
Smaller woody plants				
S	10	9	9	11
H′	.4777	.4507	1.7193	1.3836
Shrubs				
S	7	6	5	5
H′	1.6699	1.3721	1.5352	.8772
Herbs & woody seedlings				
S	31	25	20	29
H′	1.9979	2.0620	2.3300	2.5242

species other than *A. saccharum* and *F. grandifolia* (Curtis, 1959). This decline in diversity follows the finding of AuClair and Goff (1971) that a decrease in shrub diversity during initial development of climax forests is due to the complete domination by the tree species. A decline in a similar stratum in Warren Woods was noted by Brewer (1976).

Ribes sp. (Currant) and *Smilax* sp. (Greenbriar) decreased among the shrubs, while *Lindera benzoin* (Spicebush) increased during the study period (Table 5). According to Schneider (1966) *Ribes* sp. and *Smilax* sp. are shade intolerant. Their decrease accompanied by an increase in *L. benzoin,* which is characteristic of the shrub layer of moist woods (Gleason & Cronquist, 1963), seems to indicate an increased canopy cover and resultant increased shading.

The fact that *A. saccharum* was the dominant species in the smaller size classes indicates that *A. saccharum* may be succeeding *F. grandifolia* rather than being co-dominant with it (Esten, 1932). But Sterns (1951) and Bergman (1923) feel that a pure stand of *A. saccharum* is not common because any catastrophic disturbance provides a chance for other species to establish themselves. Since *A. saccharum* is clearly becoming more dominant on the north slope of Cooper's Glen, it appears that periodic perturbations will be necessary to maintain diversity by opening canopy holes that would allow establishment of species other than *A. saccharum* (Loucks, 1970). The findings of Adams and Barrett (1977) concur. They found the importance of *A. saccharum* to be greater in an undisturbed stand than in a disturbed (logged) stand. Their findings differed from ours in that *F. grandifolia* showed the same trend, while in Cooper's Glen the species seems to be declining.

SOUTH-SLOPE WOODY PLANTS. *Acer saccharum* was not the all-encompassing dominant species on the south slope that it was on the north slope. More variability was apparent since four species were denser than *A. saccharum* in the midstory (Table 6). *Fagus grandifolia, Tilia americana,* and *Quercus borealis* (Northern Red Oak) were more prevalent on the south slope than on the north slope, the result of a more open canopy. This was further evidenced by the presence of *Solidago caesia* (Goldenrod) and *Geranium maculatum* (Wild Cranesbill) in the herbaceous layer (Table 7), both of which are characteristic of open woods (Gleason & Conquist, 1963).

A general increase in density, dominance and importance of *A. saccharum* and *F. grandifolia* was found in the canopy (Table 2). This was accompanied by a large increase of *A. saccharum* in the 3′–1″ dbh stratum (Table 6). This indicates that the south slope is succeeding toward a mature beech-maple stand. As this succession occurs one would expect an increased canopy cover. This is indicated by the decrease in density of *Ribes* sp. and *Smilax* sp. and an increase of *Lindera benzoin* and *Cornus florida* (Flowering Dogwood) (Table 5), the latter two species being shade tolerant (Gleason & Cronquist, 1963). That the canopy of the south slope is not yet as complete as that of the north slope (Robinson, 1966) is illustrated by the presence and increase of *Rubus* sp. (Blackberry) and *Rhamnus catharticus* (Buckthorn) (Table 5), both of which are characteristic of open woods (Fernald, 1950).

Diversity decreased in all strata on the south slope except in the herbaceous and midstory tree layers (Table 8). Diversity declined in the 3′-1″ dbh stratum even though the number of species increased. This was due to a large increase in *A. saccharum* density in this stratum. Theoretically increased diversity among midstory trees indicates an increasingly diverse canopy in the ensuing forest. But if one looks at the species responsible for the increase, one can see that they are generally considered common understory species of a mesic forest and therefore not capable of becoming part of the canopy.

Acer saccharum and *F. grandifolia* showed an increased midstory density (Table 4) and increased dominance in the canopy (Table 2), while the other species declined in these parameters. This indicates that the south slope is succeeding toward a beech-maple forest with *F. grandifolia* becoming more important in the ensuing forest since it was the most important species of the midstory in 1975 (Table 4). The structure of the south slope woods will probably become more like Warren Woods, where *F. grandifolia* outnumbers *A. saccharum* in the canopy (Brewer, 1976), than the north slope woods of the Glen where *A. saccharum* was by far the most abundant species.

NORTH- AND SOUTH-SLOPE HERBACEOUS PLANTS. Herbaceous vegetation on the north slope of Cooper's Glen decreased in density by 50% (Table 7) while diversity increased only slightly (Table 8) between 1960 and 1975. Since the forest canopy determines the amount of light penetration and therefore the composition of the herbaceous vegetation (Clayberg, 1920), this decline can be attributed to the increased amount of shade cast by increasingly dominant *A. saccharum* and *F. grandifolia.* Density of herbaceous plants increased on the south slope (Table 7) during the study period as did diversity (Table 8). Two of the species showing large increases in density, *Viola* sp. (Violet) and *Hepatica acutiloba* (Hepatica), are commonly found in moist woodlands (Fernald, 1950). *Osmorhiza claytoni* (Sweet Cicely) decreased in density while *Prunella vulgaris* (Self-heal) and *Podophyllum peltatum* (May apple) disappeared entirely from the study tract between 1960 and 1975 (Table 7). This could be interpreted as evidence for increasing canopy cover since these species generally prefer an open woods (Fernald, 1950; Gleason & Cronquist, 1963).

Slight increases in herbaceous diversity on both slopes of Cooper's Glen agree with the results of Schneider (1966), who found increased floristic richness in the herbaceous layer of an old growth sugar maple-beech woods in southern Michigan.

Tree seedlings generally decreased in density on both slopes throughout the study period except for *Acer saccharum* which showed a large increase on the south slope (Table 7). This was a result of the increasing dominance and shading by *A. saccharum* and *F. grandifolia.*

Factors other than succession undoubtedly play a role in the dynamics of this forest stand. According to Schneider (1966), fluctuations in herbaceous vegetation need not represent cyclic changes. They may be due to simple death of one species followed by germination of another with no casual relationship involved.

SUMMARY

A beech-maple woods in Kalamazoo County, Michigan, was sampled in 1960 and again in 1975. The north-facing slope may be considered climax sugar maple-beech forest as indicated by decreasing diversity at all levels except the herbaceous layer and increasing importance, dominance and density of *A. saccharum* and *F. grandifolia.* The south-facing slope of Cooper's Glen is succeeding toward a beech-sugar maple forest as indicated by increased density of *A. saccharum* and *F. grandifolia* in the midstory and increased dominance of these species in the canopy. *Acer saccharum* showed a large increase in the 3′–1″ dbh stratum also. *Acer saccharum* was not the all-encompassing dominant of the south slope that it was on the north slope since four other species, including *F. grandifolia,* were denser in the midstory. This fact leads one to believe that *F. grandifolia* will become more important in the ensuing forest and probably become co-dominant with *A. saccharum.*

We wish to thank Richard Brewer and Joseph Engemann of Western Michigan University for advise on the project and critical reading of this paper. We are indebted to Dee LaBatt for the use of his data and to The Kalamazoo Nature Center for allowing us to make this study. We owe appreciation also to Tim W. Kendall for making the map used in Figure 1.

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CONTENTS

Some Very Common Grasses
Winifred O. Moore 167

Dalibarda repens Confirmed in Michigan
Peter B Gorton, Daniel Townsend & Karyn Townsend 189

Studies on Michigan Chrysophyceae. IV
Daniel E. Wujek, Michael Gretz & Mildred G. Wujek 191

Nolanea verna in North America
Samuel J. Mazzer 195

Fifteen Years of Change in a Southwest Michigan Hardwood Forest
Peter E. Zager & Richard W. Pippen 201

On the cover: Sitka Clubmoss (Lycopodium sitchense)
in a roadside borrow pit; Chippewa Co., Michigan, July 6, 1973
(From a color transparency by E. G. Voss)

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Vol. 17, No. 1

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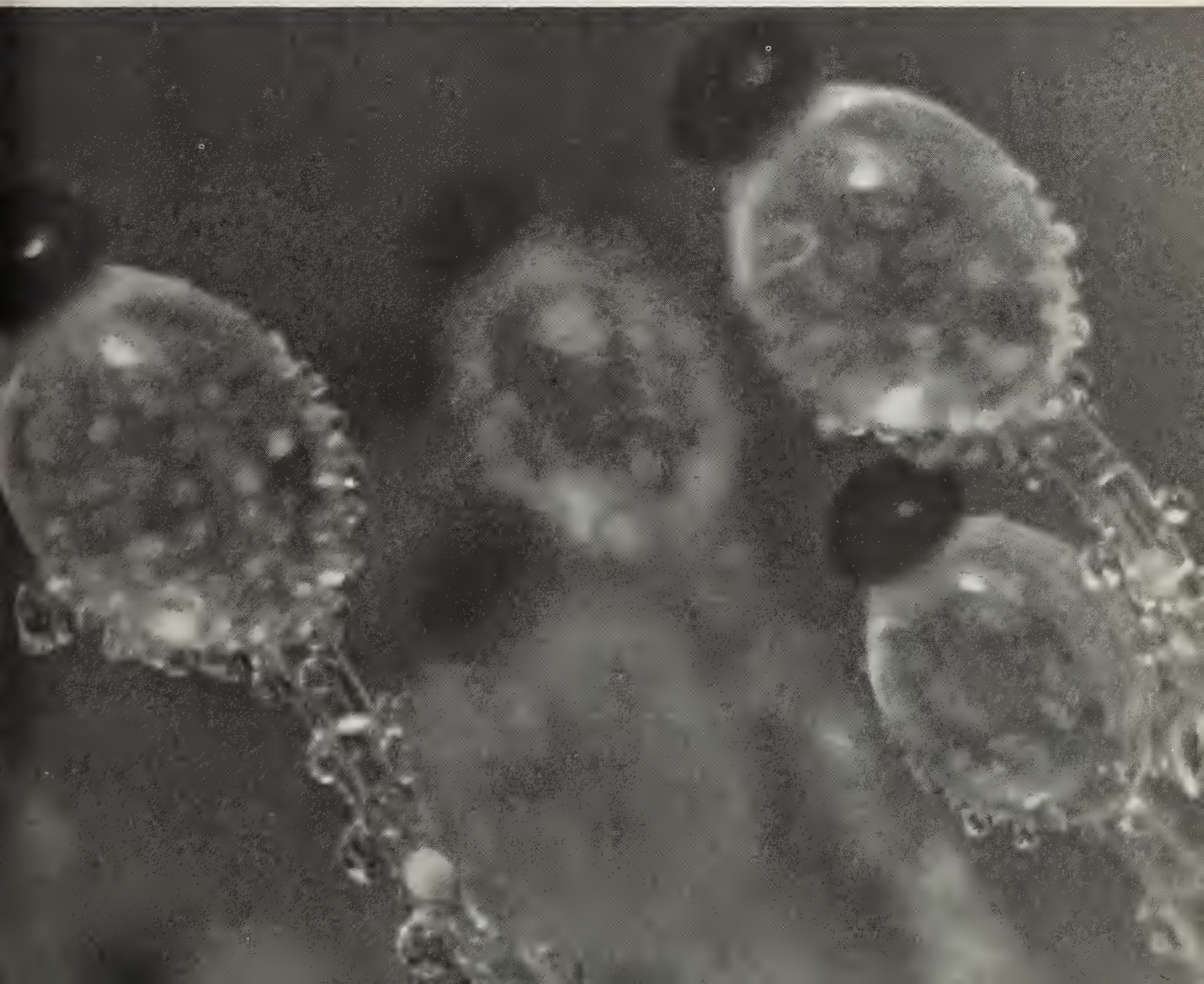

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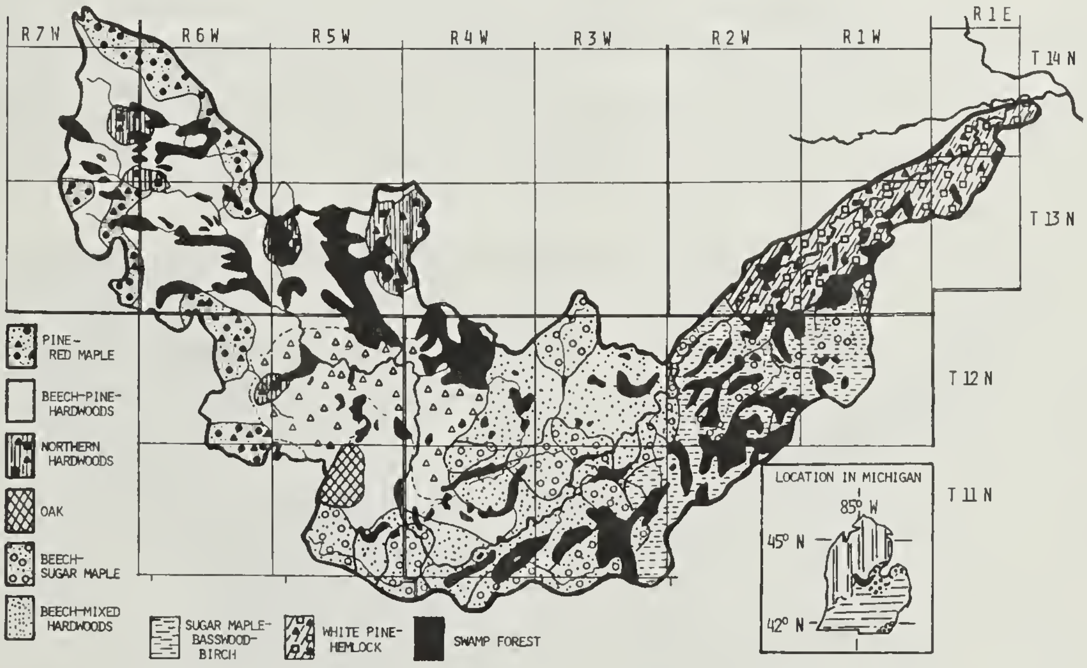
PRESETTLEMENT FORESTS OF THE PINE RIVER WATERSHED (CENTRAL MICHIGAN) BASED ON ORIGINAL LAND SURVEY RECORDS

Ronald O. Kapp
Alma College, Alma, Michigan, 48801

The history and present status of vegetation of the Pine River watershed have been the focus of an extended research program at Alma College. Pollen analysis of lake sediments has permitted the reconstruction of late glacial and postglacial vegetational changes in the headwaters of the river near Vestaburg (Gilliam et al., 1967) and Blanchard (Kapp et al., ms.). These studies and more recent research at Crystal Lake (Montcalm County) suggest that it will be possible to detect movements of the vegetational ecotone (tension zone of Potzger, 1948) which transects this central Michigan area. Other related research includes surveys of the floodplain forests of Pine River, analysis of floodplain ecosystems, and land use studies of the watershed. This paper reports an analysis of the vegetational data from the general land office survey (G.L.O.S.) records in an effort to reconstruct presettlement forest patterns in this phytogeographic transition zone.

The major vegetational transition of central lower Michigan (see insert, Fig. 1) is a reflection of the limits of the botanical ranges of several forest species. Three species of pine, black spruce, balsam fir, and hemlock reach their southern limits of continuous distribution in or near this belt, between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R 1 E
T 14 N
T 13 N
T 12 N
T 11 N
PINE-RED MAPLE
BEECH-PINE-HARDWOODS
NORTHERN HARDWOODS
OAK
BEECH-SUGAR MAPLE
BEECH-MIXED HARDWOODS
SUGAR MAPLE-BASSWOOD-BIRCH
WHITE PINE-HEMLOCK
SWAMP FOREST
LOCATION IN MICHIGAN
85° W
45° N
42° N

Fig. 1. Presettlement forest map of the Pine River watershed. Insert shows location of watershed with respect to the Eastern Deciduous Forest region (horizontal lines), the elm-ash forest of postglacial Lake Saginaw (dotted) and the Great Lakes Conifer-Mixed Hardwood Forests (vertical lines), after Küchler, 1964. Where white pine was especially abundant within the beech-pine-hardwoods type the symbol △ was added; similarly high density of sugar maple in the bass-wood-sugar maple–birch type is denoted by the symbol O.

43° 20′ and 43° 40′ N latitude. Near the Great Lakes shoreline, especially along the east shore of Lake Michigan, these species extend farther south. Certain deciduous hardwoods, notably swamp, bur, black, and chinkapin oaks (*Quercus bicolor, Q. macrocarpa, Q. velutina,* and *Q. muehlenbergii*), shagbark and pignut hickories (*Carya ovata* and *C. glabra*), hackberry (*Celtis occidentalis*), eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), and flowering dogwood (*Cornus florida*), reach their northern distributional limits in this area. Transeau (1905), Nichols (1935), Braun (1950), Küchler (1964), and others have defined this as the contact between the Eastern Deciduous Forest Region (primarily oak-hickory and beech-sugar maple forest associations) and the Great Lakes pine-hemlock-mixed hardwood forests. The distributional range of eastern hemlock (*Tsuga canadensis*) has been recognized by Nichols (1935) and Potzger (1948) as especially significant in establishing this boundary.

A report by Hushen et al. (1966) on the presettlement forests of Montcalm County included an interpretation of the relationship between major soil types and presettlement forest communities. A presettlement forest cover map was published for Montcalm County postulating the boundaries of seven forest types: beech-maple, pine-red maple, beech-mixed hardwood, beech-pine-hardwood, oak, hemlock-pine-hardwood, and swamp forests. The northeastern corner of Montcalm County is in the Pine River watershed. The current paper extends earlier attempts at presettlement forest reconstruction in central Michigan by about 400 square miles and examines forest history within a watershed area rather than according to political boundaries.

METHODS FOR ANALYZING SURVEYOR'S RECORDS

Davis (1907), Kenoyer (1930, 1934, 1940, 1943), Dick (1937), Hartesveldt (1951), Merk (1951), Bourdo (1956) and Hushen et al. (1966) have used notes of the original land survey to reconstruct the original forest of parts of Michigan. Such studies are based on the two basic types of information which may be retrieved from G.L.O.S. records.

First, general observations and summaries by the surveyors are available. At the conclusion of the survey of each township, general notes (sometimes sketch maps) were made of forest and land type patterns. These summaries were based on notes recorded as to type of forest cover and land quality. Such observations were frequently recorded following the establishment of a survey line along the one-mile boundaries of each section of land platted. The annotations were usually rather general (for example, "Land generally level, low and wet–some dryer places of 2^d rate soil; timber mostly a small growth–ash, elm, beech, lynn, etc." for the south boundary of Sec. 33, T12N, R1W) but were obviously helpful to lumbermen and homesteaders selecting land and are helpful in current research. Swamp boundaries and stream locations were noted with precision. These notes by the surveyors provide a synoptic overview of the original vegetational patterns.

A second and more precise source of information may be recovered from the surveyors' notes, albeit involving much more tedious transcription of information. Quantitative data are retrievable from the records of witness trees which were "blazed" in order to relocate the corner posts established at each section and quarter-section corner. The original land survey of the Pine River watershed was completed in the period 1832-39; although there were minor alterations in the survey instructions, the selection of witness trees was sufficiently uniform to permit use of the data for this study. The surveyors were instructed to mark two witness trees, closest to the corner and in different quadrants, at each section and quarter-section corner. The species of tree, its diameter in inches, and the direction and distances in links from the corner posts were recorded in notebooks which are usually retained at county courthouses; transcriptions of these records are available for inspection at the Lands Division of the Department of Natural Resources, Lansing. In addition to the survey corner witness trees, the surveyors usually placed a double blaze on each tree intersected by the section line; the identity and diameter of two or three such "line trees" were also recorded in the notebooks. The identities of the witness trees were noted by standard abbreviations which have been deciphered using botanical manuals of the survey era. These abbreviations and the corresponding modern scientific nomenclature are listed in Hushen et al. (1966). The system of establishing a square grid pattern of sections and the records of witness trees at half-mile intervals on this grid provide a series of systematically-placed sample points in the original forests. The types of trees recorded and distances to the corner posts therefore approximate a random sample of the species composition and distributional patterns of these former forests. The degree of bias in selection of witness tree species is the only substantial source of error or skew in these data. A certain amount of judgment in selection of witness trees is permitted ("alive and healthy and not less than five inches in diameter") or even encouraged ("the soundest and most thrifty in appearance, and of the size and kinds of trees which experience teaches will be the most permanent and lasting") in the survey instructions. Bourdo (1956) discussed the evaluation of surveyors' bias and outlined techniques for testing for bias in the survey data. Bias tests were run on the

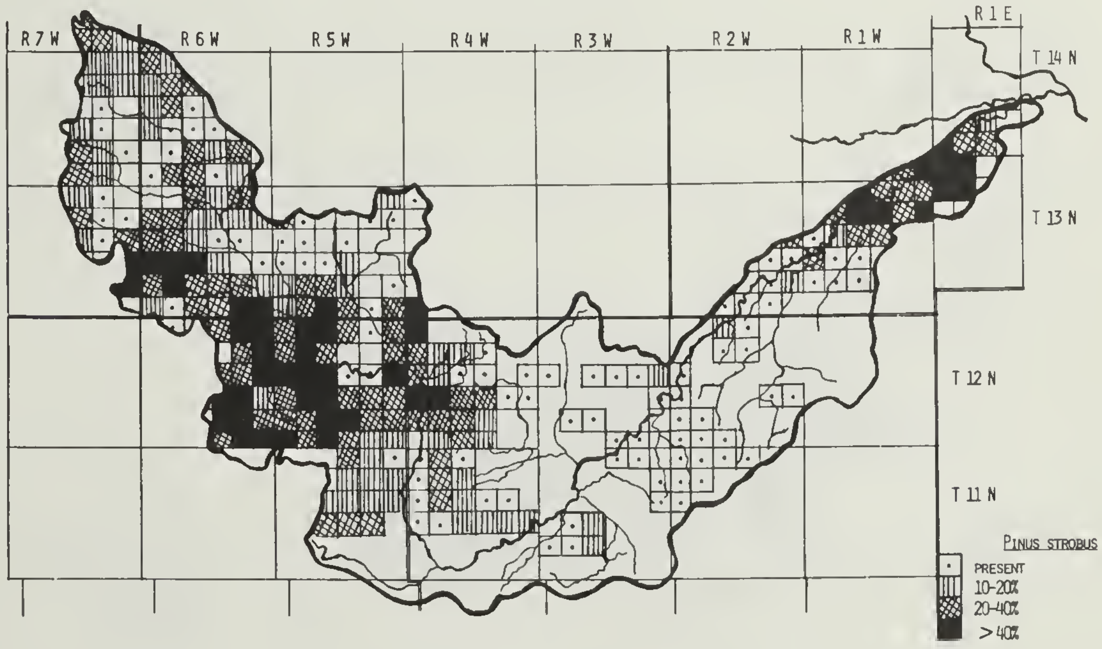

Fig. 2. Presettlement distribution and dominance of *Pinus strobus* in the Pine River watershed.

Montcalm County data by determining the statistical probability for observed mean distances from corner posts to the dominant tree species within each of three major forest types; Hushen et al. (1966) concluded that the level of bias was negligible. Since the Pine River watershed was surveyed in the same period (1831-39, except for interior subdivisions of T13N, R2-3W and T11-12N, R2W in 1852) by various combinations of the same deputy surveyors, it is assumed that the records used in this study contain minimal bias.

The following methods were used in preparing the species distribution and presettlement forest maps presented in this paper. The location and identity of each witness and line tree, as well as other survey data, were recorded on quarter-township (3 X 3 mi.) working plat maps and eventually (by tree symbols) on a map of the entire watershed. Species dominance maps (Figs. 2-8) were developed by calculating the percentage of the total trees surrounding a certain section represented by a given species. Typically 16 witness trees were recorded for an "internal" section of lands, that is, for a section not located on a township line. Usually for such a section a total of 20-24 trees was included

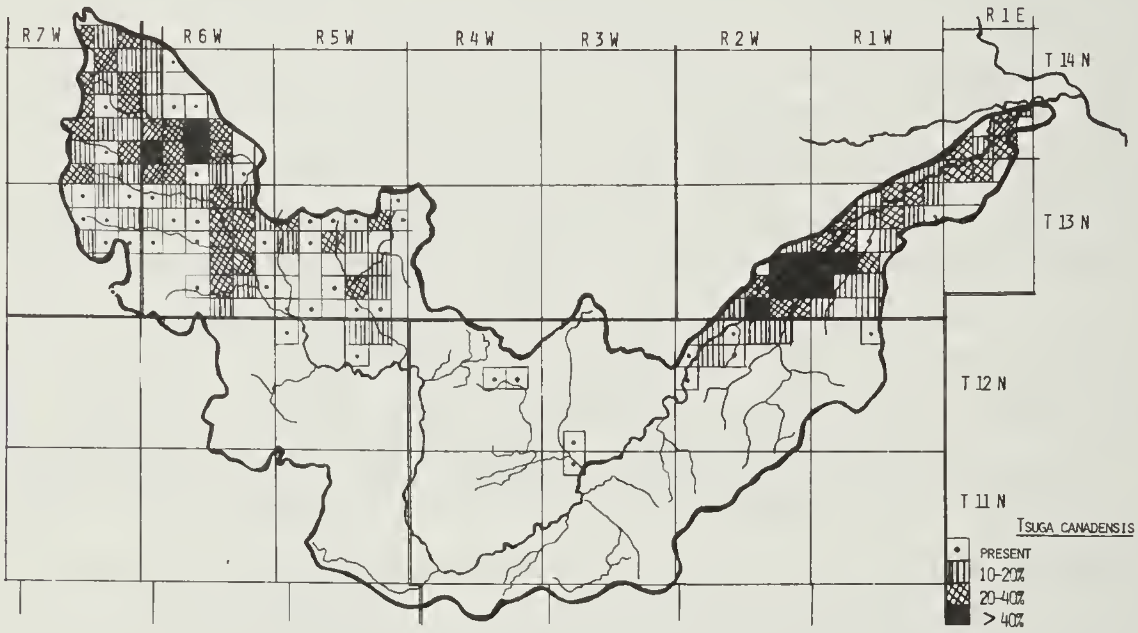
R7W
R6W
R5W
R4W
R3W
R2W
R1W
R1E
T14N
T13N
T12N
T11N
TSUGA CANADENSIS
PRESENT
10-20%
20-40%
>40%

Fig. 3. Presettlement distribution and dominance of *Tsuga canadensis* in the Pine River watershed.

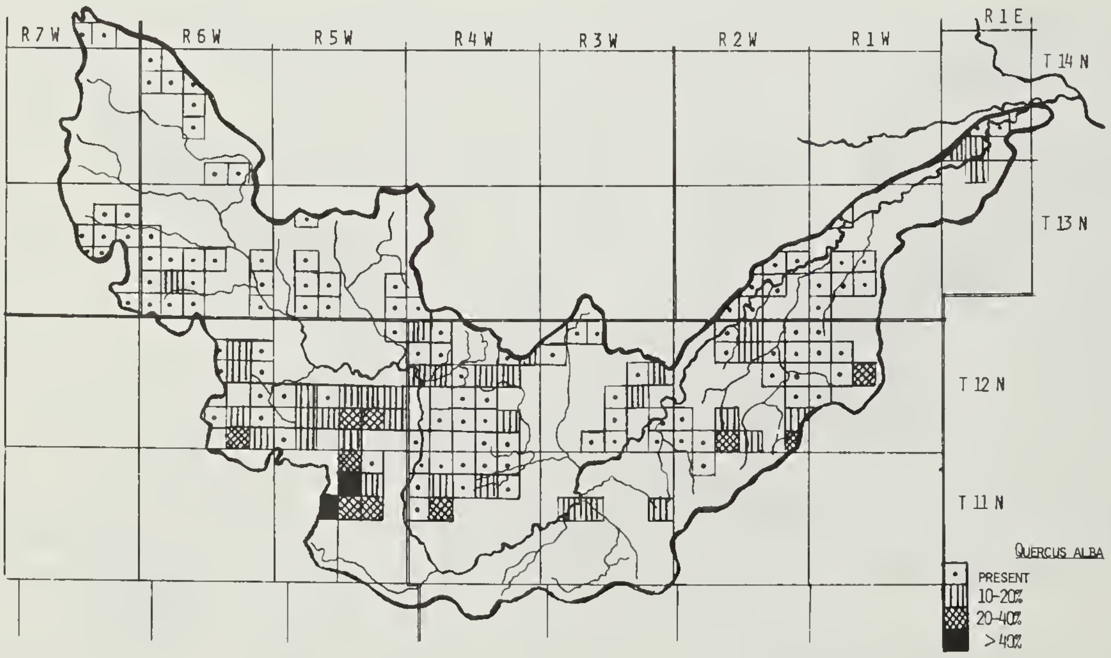
R7W
R6W
R5W
R4W
R3W
R2W
R1W
R1E
T14N
T13N
T12N
T11N
QUERCUS ALBA
PRESENT
10-20%
20-40%
>40%

Fig. 4. Presettlement distribution and dominance of *Quercus alba* in the Pine River watershed.

in the sum, depending on the number of line trees noted and the frequency of occasions that the section corner was itself marked by a single witness tree. Sections of land along township lines were marked with additional witness trees, four at each half-mile survey post; frequently 30-34 trees were recorded for these sections. Overall an average of about 25 trees per section was analyzed for the dominance of various forest trees and establishment of forest community boundaries.

Species maps were prepared showing the distribution and dominance of several common species in each section of land within the watershed; these include white pine (*Pinus strobus*, Fig. 2) and eastern hemlock (*Tsuga canadensis*, Fig. 3), which reach their southern distributional limits in the watershed, white oak (*Quercus alba*, Fig. 4), sugar maple (*Acer saccharum*, Fig. 5), American beech (*Fagus grandifolia*, Fig. 6), red maple and basswood (*Acer rubrum* and *Tilia americana*, Fig. 7), and swamp forest species (including *Ulmus spp., Fraxinus nigra, Larix laricina, Thuja occidentalis,* and *Salix nigra,* Fig. 8). The generalized presettlement forest-type map (Fig. 1) was constructed on the basis of distribution shown on the species maps and by taking into account the surveyors' notations about swamp and forest-type boundaries.

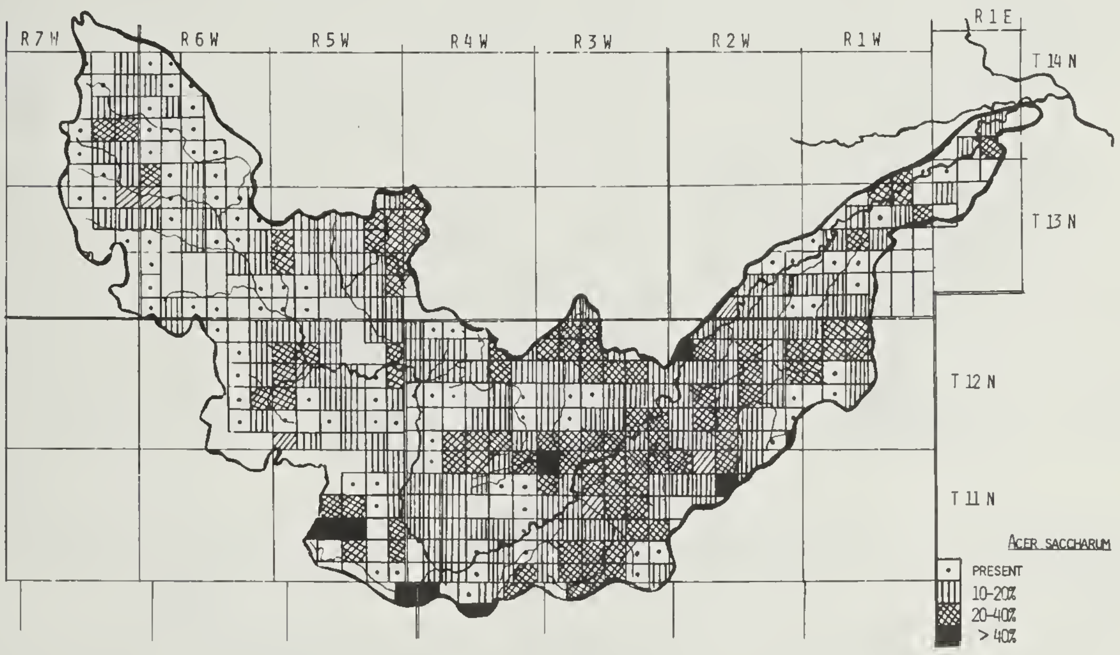

Fig. 5. Distribution and dominance of *Acer saccharum* in the presettlement forest of the Pine River watershed.

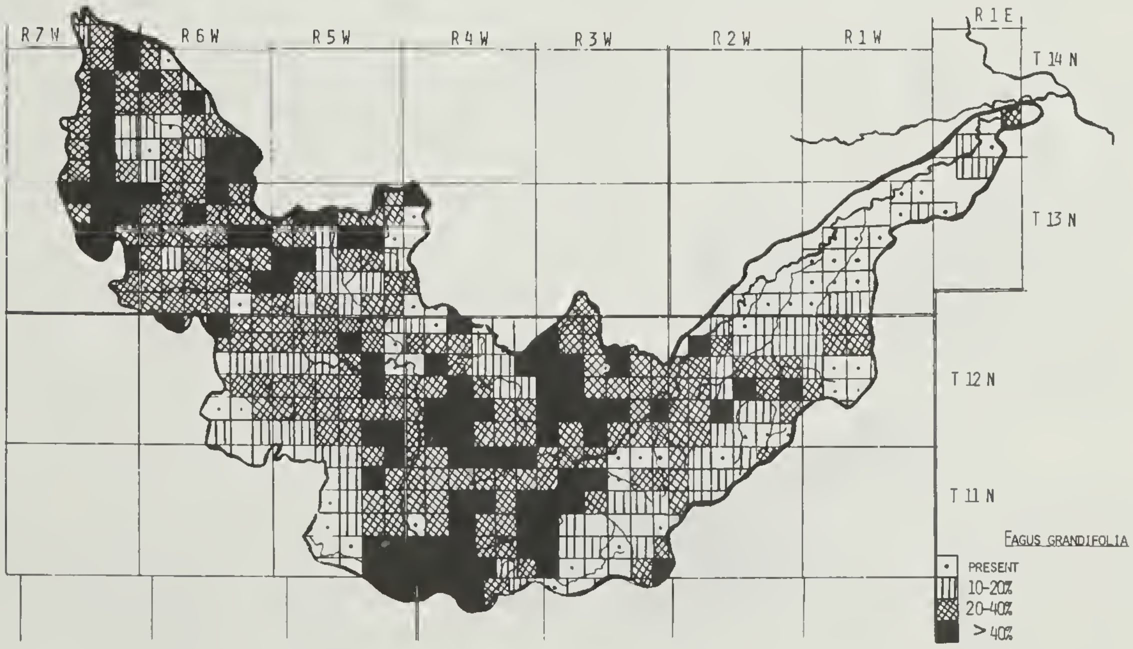

Fig. 6. Distribution and dominance of *Fagus grandifolia* in the presettlement forests of the Pine River watershed based on surveyors' witness trees.

PRESETTLEMENT FOREST PATTERNS

Distribution of Selected Forest Species.

Perhaps it is appropriate to begin with discussion of the species for which the river and watershed were named. *Pinus strobus* reaches its southern distributional limit in T11N of central Michigan although it extends farther south on both the western and eastern counties of Michigan (Voss, 1972). This species has wide ecologic amplitude and can be found in as diverse habitats as deep, dry, sandy soils and swamps or bogs. It reached its highest presettlement abundance near the confluence of the Pine and Chippewa Rivers on the sands and deep clays of postglacial Lake Saginaw (Fig. 2); the predominant soils there are Rubicon sand, Arenac sandy loam, and Genesee sandy loam (Johnsgard et al., 1950). Some of the finest virgin "cork pine" to

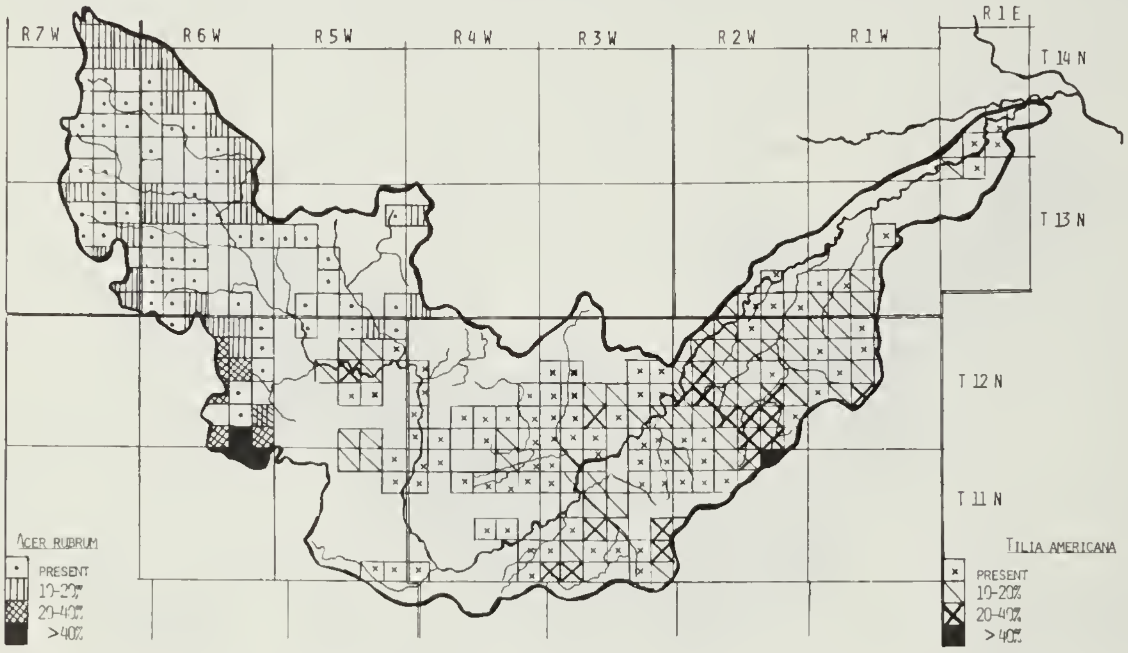
R7W
R6W
R5W
R4W
R3W
R2W
R1W
R1E
T14N
T13N
T12N
T11N
ACER RUBRUM
PRESENT
10-20%
20-40%
>40%
TILIA AMERICANA
PRESENT
10-20%
20-40%
>40%

Fig. 7. Presettlement distribution and dominance of *Acer rubrum* and *Tilia americana* in the Pine River watershed based on the surveyors' witness trees. The species were non-overlapping in distribution except for four basswood witness trees (not plotted on map) in R6W and R7W.

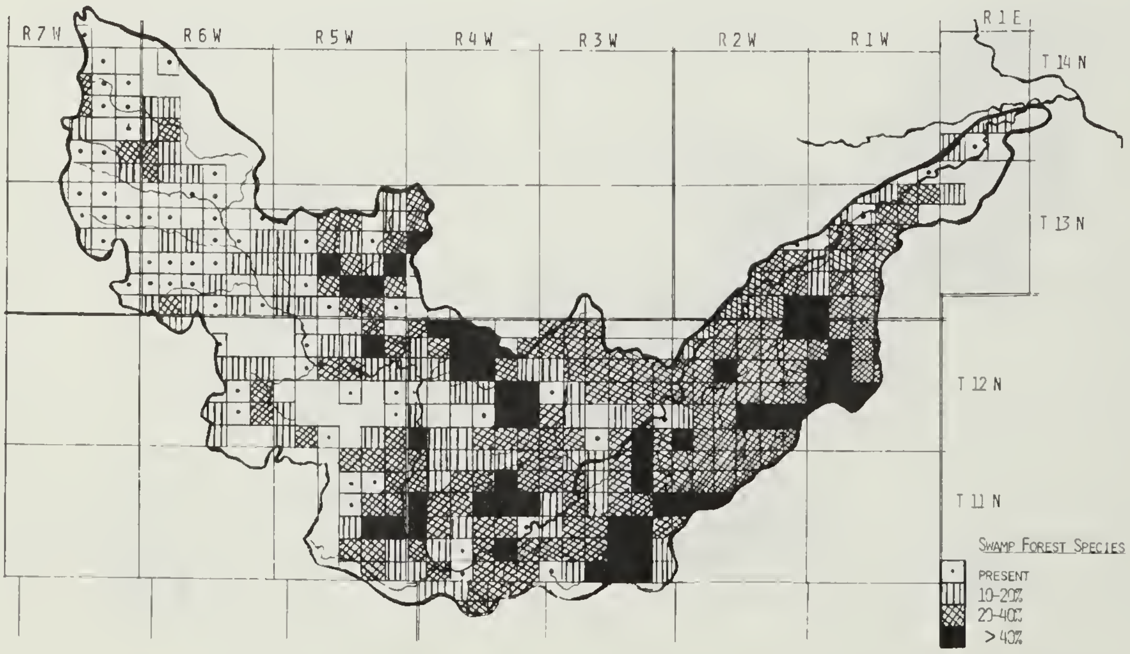
R7W
R6W
R5W
R4W
R3W
R2W
R1W
R1E
T14N
T13N
T12N
T11N
SWAMP FOREST SPECIES
PRESENT
10-20%
20-40%
>40%

Fig. 8. Distribution and density of swamp forest species in presettlement forests; records for elm, black ash, tamarack, white cedar and willow were summed to prepare these data.

reach mid-nineteenth century Saginaw sawmills was harvested from similar sites along the Cass River in adjacent Saginaw and Tuscola Counties as early as 1847 (Mills, 1918). It is interesting that white pine should have been such an important timber resource on sites so near its distributional limits. An eyewitness account of the timber between St. Louis (Michigan) and the Chippewa confluence is recorded in a February 22, 1859 letter of a German homesteader who lived on the Tittabawassee River and travelled to St. Louis.

> A few days ago missionary Miessler was here, and as there was no sleighing for logging and I had long been interested in seeing the area around Pine River, I had my horse saddled and rode with him. At first, 12 miles to Midland, where the main trees were pine, hemlock, poplars and birches and where we crossed the Tittibawassee, 2 miles on the Chipway, which flows into the Pine River. The pine woods belong to a Canal Co., from Sault St. Marie. Now we rode through woods uninterruptedly for 15 miles, where we saw strong bear tracks and many deer tracks. Farther on we got to an old pinery, where fire had done much damage two years ago. From this chaos we again entered the primeval wilderness. We ate our noonday meal in the saddle, while the poor ponies had to keep going with empty stomachs, and for that we let them drink as often as they wanted to. 7-1/2 miles farther on we got to the camp of a pinery, 7 men and three yoke of oxen, which already has 1,100 logs at the river-bank. (Frank, 1971.)

White pine was also abundant (commonly 50-60% of the witness trees recorded) in northeastern Montcalm County (T12N, R5-6W) and in adjacent Isabella County. The dominant soils in this area are light sands (Grayling series) and loamy sands (especially Mancelona and Gladwin loamy sands). The areas in which white pine was a dominant presettlement forest component are still easily identified because the stump fences persist along the borders of farm fields.

Dozens of sawmills were operated in Saginaw for a 50-year period from 1845 to 1895; lumber production from these mills had reached 92 million feet by 1851 and peaked at more than one billion board feet per annum in 1882. In addition, shingle production began to boom by 1867, with 61 million pieces, and peaked in 1881, with 305 million pieces (Mills, 1918). The demand for land and harvest of the timber resources from the tributaries of the Saginaw River was extremely rapid during this period; the nearby Cass and Flint Rivers were lumbered first, followed by the Tittabawassee, Chippewa, and Pine. White pine was selected for earliest removal and rafted down the streams in spring "booms." In fact, the earliest navigational rights controversy on the Pine River seems to have developed at the site of Alma in 1856, when Ralph Ely protected his right to continue to "boom pine" and removed the first dam which had been constructed at Alma (Tucker, 1913). Subsequently sawmills and shingle mills were built at Elm Hall, Riverdale, and other riverside sites near the source of timber, primarily to capitalize on the abundance of white pine in the western part of the watershed.

Apart from selective lumbering and activities at the Bethany Lutheran Indian Mission near St. Louis, which was founded in 1848, the first white settlers arrived in the watershed during 1853-56 (Tucker, 1913). Hard winters and wet soils made settlement difficult and most of the pioneers of "starving Gratiot" were still selling timber and splitting shingles to maintain life itself in 1857-58. White pine timber provided the impetus for completing the final section line surveys (in 1852); it also provided the motivating force for opening the watershed to settlement against formidable ecological barriers, and it sustained many of the earliest settlers until the land could be properly cleared and drained.

Tsuga canadensis (Fig. 3) also reached its southerly distributional limits within the watershed. It favored moist and mesic sites and was most abundant (40-50% of the witness trees) on lake clays and sands along the river in Midland County (T13N, R1-2W). It was also common on ground moraines and certain outwash plains in the headwaters region (T14N, R4-7W, Isabella and Mecosta Counties). It was least common on the end moraines which, in the western part of the watershed, tend to be well drained or dry, having light soils. Occasional trees were recorded south of the area of continuous distribution, primarily on heavier soils and along tributaries of the Pine River. Whether these occurrences were indications that hemlock was extending or had recently contracted its range is a matter for inconclusive speculation. In combination with sugar maple, beech, red oak, and white pine, it is a key component of the mesic northern hardwoods forest type which covered limited areas of the presettlement forest mosiac.

Quercus alba (Fig. 4) was found in low frequency throughout the presettlement forests of the watershed. It reached a dominant level (30-60% of the witness trees) only in the north half of Ferris Township (T11N, R5W), Montcalm County; only there is the oak forest type identifiable within this watershed. Studies by Hushen et al. (1966) identified extensive oak forests in southwestern Montcalm County (especially T9N, R8W). White oak appears to have favored sites on end moraines; it was less frequent on ground moraines and old lake beds and virtually absent on outwash (compare Fig. 9).

Black and red oak (*Q. velutina* and *Q. rubra*) witness trees were recorded only in the headwaters region; none was found south of the north boundary of T12N or east of the west boundary of R4W. They were nowhere abundant (<10%).

Acer saccharum (Fig. 4) usually recorded simply as Sugar in the surveyors' notes was found throughout presettlement forests in the watershed but

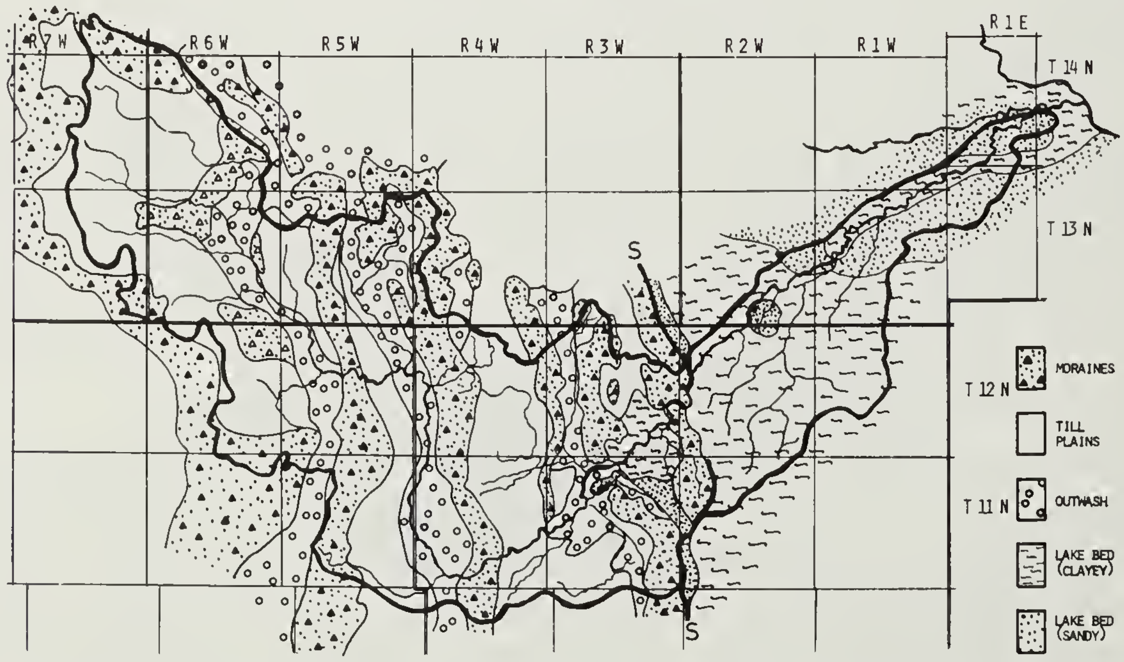

Fig. 9. Surface geology of the Pine River watershed and contiguous areas; S indicates the beach of postglacial Lake Saginaw (redrawn from Martin, 1955).

was definitely more abundant in the central and southern parts of the area. Its highest density was attained on till plains (ground moraine) or clayey end moraines, but it was nearly as common on the clay-rich lake beds of postglacial Lake Saginaw. It was infrequent to absent on dry sands (as in T13N, R1W and R1E, Midland County) and on the sandy moraines of northeastern Montcalm County (T12N, R6E). There is, as expected, a great diversity of soils on areas mapped as till plains (Fig. 9); some are fine-grained to heavy soils with adequate drainage to support mesic forests of sugar maple, beech, and other hardwoods; others were apparently too wet or dry to support *Acer saccharum* and its forest associations.

Settlers considered "sugar maple soils" to be of "superior quality" (Fox, 1858); these nutrient-rich soils (notably Capac loam, Selfridge loamy sand, Tedrow loamy sand, and Ithaca loam; Feenstra, 1976) could withstand droughty conditions and, once properly drained, were extremely productive. Only the Parkhill-loam of the clay-rich Lake Saginaw region is a more productive agricultural soil than those mentioned; here also there were moderate to high presettlement densities of sugar maple (as in R2W); some such sites, since drained and highly productive, were originally too wet for *Acer saccharum.*

Fagus grandifolia, the companion of sugar maple in the much-discussed beech-maple climax forests of the southern Great Lakes region, was the most frequently recorded tree in the surveyors' notes (Fig. 6). One would suspect consistent selection bias in favor of this easily blazed, smooth-barked species, yet our bias analysis based on mean distances to survey posts (Hushen et al., 1966) show a low probability (p = .01–.02%) that there was non-random selection.

Beech was most abundant on moraines (compare Figs. 6 and 9); in almost all instances in which the density was greater than 50% the survey sections were located on end moraines. Distribution was variable on glacial outwash; commonly densities were less than 20%. Beech was most sparse and frequently absent from sandy areas near the river's terminus in Midland County (T13N, R1-2W).

Tilia americana prefers sandy loams, loams, and silt loams on clay subsoils in Michigan (Fowells, 1965); this is reflected by its highest presettlement densities on the clayey lake beds of postglacial Lake Saginaw (Fig. 7; R2W). These sites are primarily on the Parkhill loam, Capac loam, and Metamora-Capac sandy loam soils of Gratiot County (Feenstra, 1976). In the central part of the watershed the distribution follows the streams; here basswood was originally, and still may be found on alluvial soils. This species was virtually absent in the headwaters, presumably because of the scarcity of silty alluvium or other suitable soil matrix.

Acer rubrum (red maple) was restricted to the headwaters area of the watershed (Fig. 7). The species was most abundant (as in T12N, R6W) on Montcalm loamy sand and sandy loams of 6-10% slopes and on Montcalm and McBride loamy sands and sandy loams, on 2-6% slopes. These soils are subject to erosion because of their sandy character (Schneider, 1960). In Isabella County red maple was most common on Plainfield sand (Kerr &

Thrull, 1928). Red maple was not restricted to morainal substrates, however, as it was moderately abundant on outwash (T13-14N, R6W; Sec. 2, T12N R5W). This distribution reflects the preference of *Acer rubrum* for ecological extremes, either wet, even swampy or dry, xeric conditions. The species was completely absent from the central and eastern parts of the watershed. A very few silver maples (*Acer saccharinum*) were marked as witness trees in the survey of this watershed. They were on alluvial soils; presumably their sparseness reflects the proximity of the northern range limit of the species. Analysis of the modern floodplain forests (Povich, 1975) indicates that while silver maple is found on the Pine River floodplain in T13N R6W and beyond, in the headwaters area it is replaced as the commonest floodplain species by red maple and by northern white cedar (*Thuja occidentalis*) and tamarack (*Larix laricina*).

Swamp Forests.

Settlement of the Pine River watershed was retarded because of a reputation as a wet and unhealthy area based primarily on the character of the poorly drained, swampy, postglacial lake beds of R2W and eastward. Comments in surveyors' notes, such as those of deputy surveyor Robert Clark, Jr., on May 26, 1831, "good for raising muskitoes", would not have encouraged a rush of homesteaders. Surveying and later homesteading were both made difficult, especially in wet seasons, by the prevalence of swamplands. The 1871 state law which assisted drainage of swamplands was apparently instrumental in the agricultural development of the watershed; the first major project was the drainage of "The Big Swamp" of T11-10N, R2W) in 1873 (Tucker, 1913).

While the presettlement swamp forests were largest and most continuous on the postglacial lake beds (Figs. 8 & 9), they were also extensive on till plains and outwash areas in the central section. Figure 8 plots the combined densities of the following swamp (or predominantly wetland) forest species: elms (*Ulmus rubra* and *U. americana* were usually not separated by the surveyors); black ash (*Fraxinus nigra*), willow (*Salix nigra*), tamarack (*Larix laricina*), and northern white cedar (*Thuja occidentalis*).

Thuja records are restricted to the headwaters area, primarily T13-14N, R5-7W. In presettlement times, as at present, white cedar was abundant in swamps and on mucky soils along the Pine River and its tributaries. Notable eastward extensions of this distribution are cedar swamps near springs fed by the elevated water tables of end moraines in the center of T12N, R4W. In this area calcareous spring waters have in some places (e.g., along M-46 highway in S1/2, Sec. 23, T12N, R4W, Gratiot County) precipitated tufa deposits around former spring heads; a cold, wet calcareous microhabitat is thereby created which perpetuates the relict cedar swamp communities.

Picea (apparently black spruce) is a very infrequent component of the swamp (primarily bog) forests; it was recorded only 3 times by surveyors in T13 and 14N.

Larix laricina (tamarack or eastern larch) was a common component of the swamp forests in the headwaters region but was considerably more localized in the south-central sector. This species was virtually absent from the swamp forests of the Lake Saginaw sector. There the swamps were primarily black ash and elm.

Swamp forests were most extensive in the Lake Saginaw sector where the subsoil was clayey (T12N, R1-2W); there wetland species comprised 20-80% of the witness trees recorded. Swamp forests were also common on glacial outwash, especially in T13N, R5W; T12N, R4W; and T11N, R3W; in certain of these areas the original south-flowing postglacial drainage patterns (tributaries of the Maple and Grand River system) became partially occluded when the Pine River developed its easterly flow into the Saginaw drainage. In some areas (e.g., T14N, R6-7W) the ground moraines had inadequate drainage and substantial areas of swamp forest existed, but, in general, the higher rolling landscape in the headwaters region resulted in smaller, restricted swamplands.

With European settlement and forest clearance, virtually all of the swampland in R3W and eastward was drained by an extensive system of open ditches and by tiling; the only extensive swampland remaining, except on floodplains, is on the agriculturally unpromising lands along the North Branch, Pine River (on outwash in T13N, R5W).

PRESETTLEMENT FOREST TYPES

The foregoing discusion of the presettlement distribution of the important forest species in the watershed describes the basic forest distribution pattern. From these an outline of the categories and components of the presettlement forest types, as mapped in Fig. 1, may be synthesized. Nine forest types have been recognized and mapped as follows:

NORTHERN HARDWOODS. Sugar maple (15-30%), beech (to 50%), hemlock (variable), white pine (<20%), red or black oak and black cherry (variable).

PINE–RED MAPLE. Red maple (10-40%), white pine (10-40%), beech (variable), white oak (usually present).

BEECH–PINE-HARDWOODS. Variable density of beech, white pine (where above 33%, designated in Fig. 1), maples and oaks.

OAK. White oak (30-60%), white pine (variable), beech (<20%).

BEECH–SUGAR MAPLE. Sugar maple (>33%), beech (variable, generally 20-50%), occasional white oak, basswood, birch or other hardwood, hemlock absent, white pine (<10%).

BEECH–MIXED HARDWOODS. Beech (20-80%), sugar maple (up to 30%, sometimes absent), occasional oak, basswood, white pine, birch or other hardwood; hemlock absent.

SUGAR MAPLE–BASSWOOD-BIRCH. Sugar maple (10-30%), beech (infrequent to 40%), basswood (usually 5-25%), paper birch (variable, usually 3-15%), white oak (variable).

WHITE PINE–HEMLOCK. Eastern hemlock (variable, usually 10-60%), white pine (variable, usually 10-60%), paper birch (variable, to 25%), occasional sugar maple, basswood or white oak.

SWAMP FOREST. Headwaters section dominated by tamarack, black ash or northern white cedar (with understory of alder); central and eastern sectors dominated by black ash and elm.

SUMMARY

Surveyors' field notes and summaries have been used to construct a presettlement forest type map for the Pine River watershed of central Michigan. The forest distribution reflects the transition between the Eastern Deciduous Forests dominated by oak-hickory and beech-maple forest types and the Great Lakes-pine-hemlock-mixed hardwood forests. The elm–ash swamp forests of the postglacial Lake Saginaw lowlands are also represented in this complex vegetational transition zone.

Individual distribution and presettlement density maps (based on surveyors' witness and line trees) constructed for eight forest species also reflect the ecotone of central lower Michigan and more firmly establish the distributional limits of eastern hemlock and white pine in this region. These distributional patterns are compared with the surface geology of the watershed and major soil types.

The assistance of Kathy VandenBosch, Phyllis Ahearn, and Cathy Dent, who assisted in reading and transcribing surveyors' notes, is gratefully acknowledged.

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HISTORY OF RECENT HABITAT CHANGES IN CENTRAL MICHIGAN

Robert L. Paterson, Jr.
Dept. of Biology, Virginia Polytechnic Institute
Blacksburg, Va., 24061

Accumulation of data concerning habitat composition and rate of change is important to both game and non-game zoologists. Sheldon (1967) showed that the American Woodcock (*Philohela minor*) will cease breeding in areas as succession alters the character of its courting ground, and Mayfield (1960) pointed out that the Kirtland's Warbler (*Dendroica kirtlandii*) requires jack pines between one and eight meters in height as nesting sites. Although some disturbance in completely forested areas is beneficial for wildlife, native populations can be degraded by changes in presettlement forest type or by rapid habitat reduction. Data concerning recent habitat distribution allow the calculation of a rate of habitat change, and knowledge of presettlement forest species composition and distribution enables comparison with similar post-settlement data in determining the altered condition of native plant and animal populations. This paper presents the history of recent habitat changes in four townships of Isabella County, Michigan, from presettlement to 1972. Special emphasis is given to the rate of change for a 14-year period between 1956 and 1972.

Isabella County is situated in a transitional zone between the northern coniferous and northern deciduous forest types (Fig. 2) which cover Michigan's lower peninsula (Nichols, 1935; Braun, 1950). The four townships (each 92 km^2) chosen as study areas were part of a large-scale project investigating American Woodcock distribution (Paterson, 1975). Land survey records indicate that the original forests were composed largely of pine, oak, and maple. These forests were cleared as the lumber industry entered the area about 1860. By 1880 approximately 38% of the county was being farmed, increasing to 86% by 1920 (Kerr & Trull, 1928). Recent data (Webb, 1972) indicate that 58% of the county is presently used for agricultural purposes and that much of the abandoned land has returned to forest cover, while some has been platted or converted to various urban developments. The areas more recently abandoned are at various secondary successional stages.

There are two extensive forest areas in the county. In the western third aspen-oak forest and beech-maple woods are extensive on appropriate sites. The forest in the east-central region of the county is small aspen, interspersed with openings at various shrubby successional stages. The characteristic plants which first invade these openings are staghorn sumac (*Rhus typhina*), witch hazel (*Hamamelis virginiana*), juneberry, and pin cherry (*Prunus pensylvanica*). Those areas along river and creek bottoms are dominated by swamp species such as elm, black ash (*Fraxinus nigra*), willow, alder (*Alnus rugosa*), and soft maples mingled with small amounts of cotton wood (*Populus deltoides).*

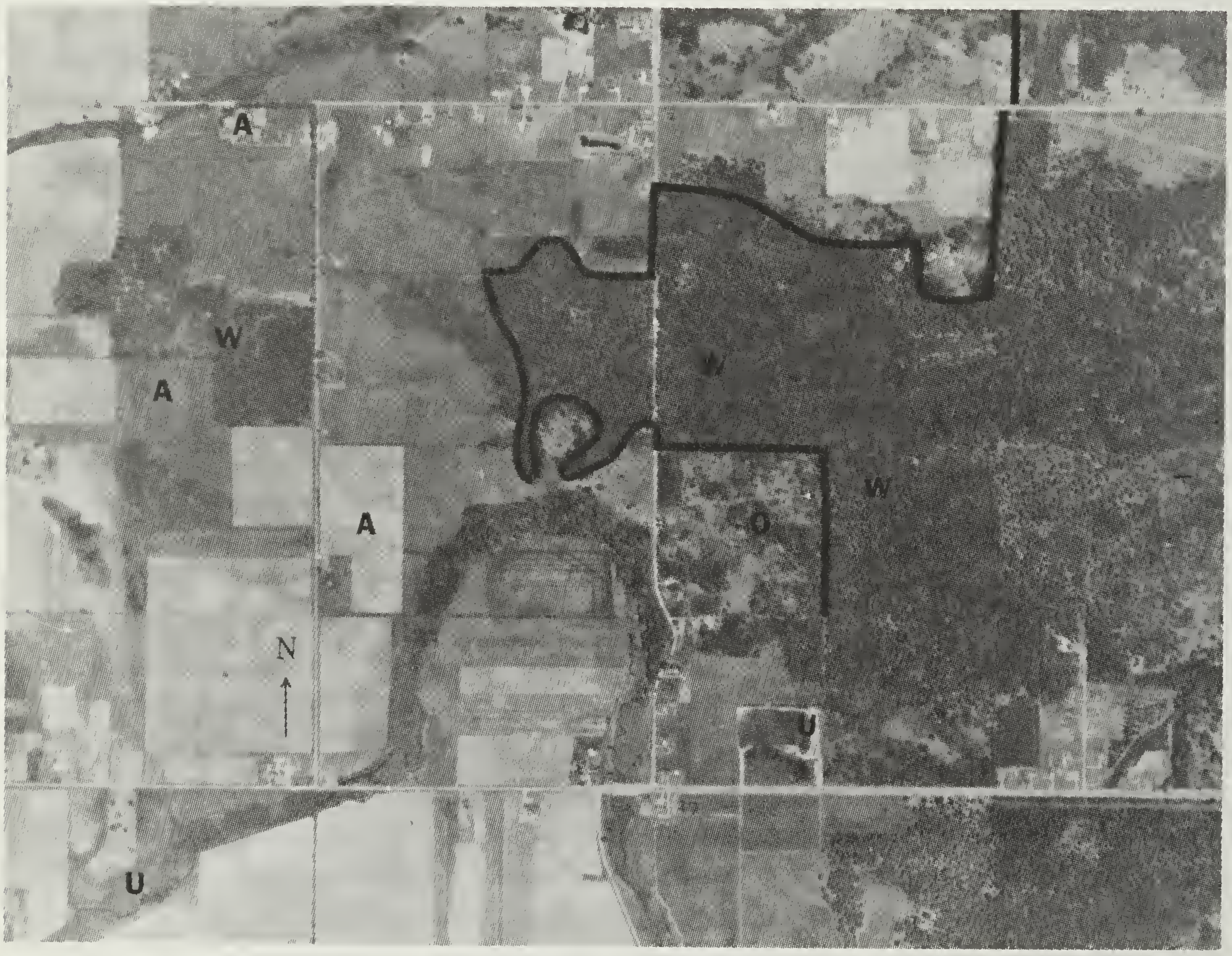


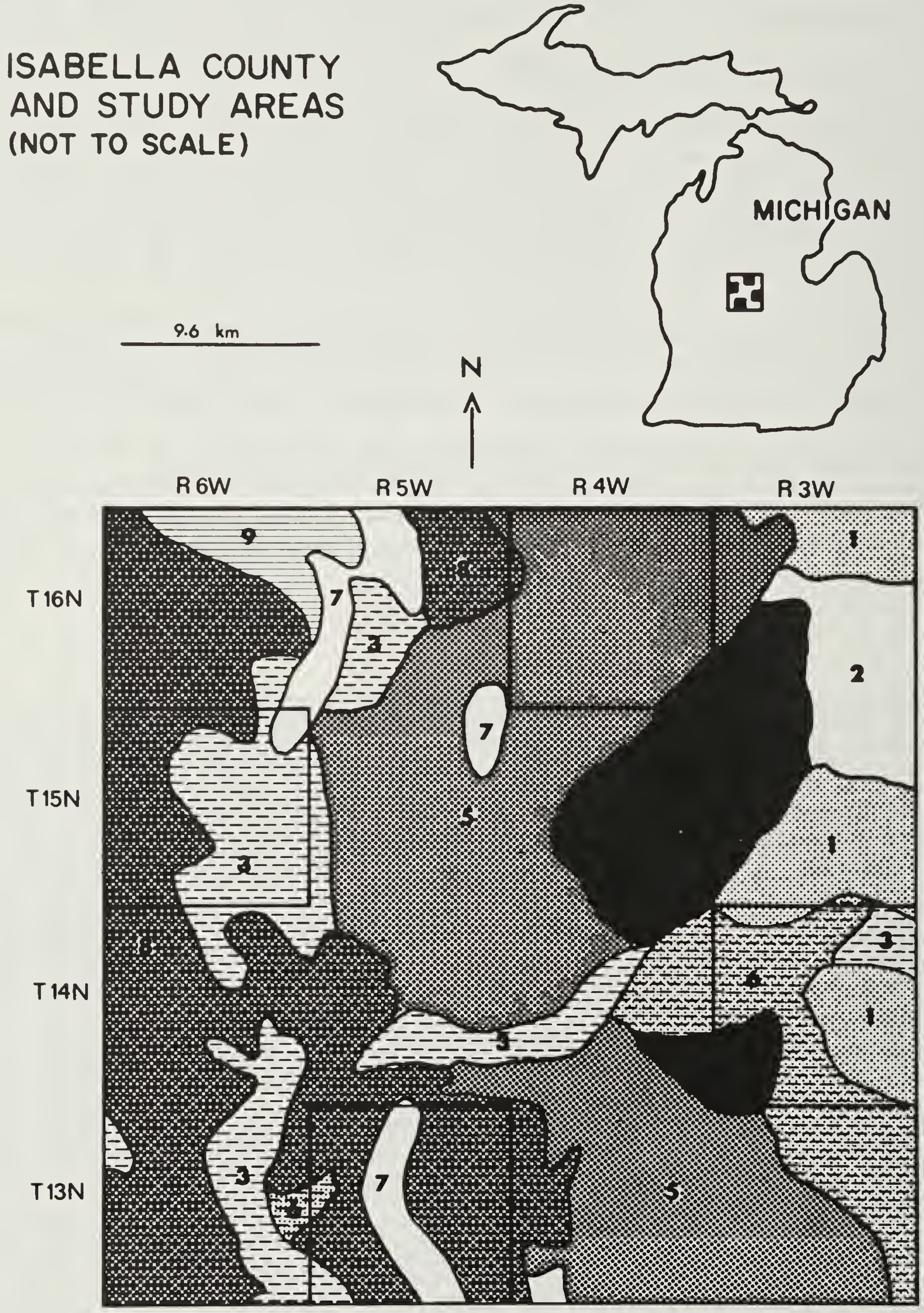
Fig. 1. Agricultural and residential land–A. Old field–O. Maturing forest–W. Unclassified–U. Dark line demarks boundaries of forest and old field.

Presettlement vegetation in the county was determined by use of Veatch's (1959) map. Post-settlement habitat types were measured on aerial photographs (scale 1 cm = 79 m) of the four townships taken in 1958, 1965, and 1972. Each 2.6 km^2 township section was divided into 64 four hectare units. Percent-cover estimates (down to 1 hectare) of old field (with shrub encroachment), farmland or residential area, maturing forest, and unclassified habitats (including recently abandoned fields without shrub encroachment, swamps, lakes, and rivers) were made of the 144 study units (Fig. 1). Results among townships were compared, and the rate of change (increase or decrease in hectares per period of time) in these habitat types over the past 14 years was calculated.

Figure 2 shows the distribution of presettlement forest. Approximately 80% of the presettlement forests occurring in the county are located in the four townships. Table 1 lists species composition, area, and percent of each

TABLE 1. The area and percent of presettlement forests in four townships.

	HECTARES	PERCENTAGE
Chippewa–T14N, R3W		
Elm, Silver Maple, Ash, Swamp White Oak, Basswood, Cottonwood	4186	45
White and Norway Pine, Oak, Mixed Aspen, Spruce, Fir, Cedar	2937	32
Silver or Red Maple, Elm, Ash, some Hemlock, White Pine	1345	14
Oak, White Pine, Aspen, Red Maple	860	9
Vernon–T16N, R4W		
Sugar Maple, Basswood, Elm, Ash, some Hemlock, White Pine	8547	92
Silver or Red Maple, Elm, Ash, some Hemlock, White Pine	520	6
Oaks, White Pine, small amounts of Sugar Maple, Beech, Hemlock	261	2
Sherman–T15N, R6W		
Oaks, White Pine, Aspen, Red Maple	4914	53
Oak, White Pine, small amounts of Sugar Maple, Beech, Hemlock	4146	44
Elm, Ash, Red Maple, Swamp White Oak, Tamarack	268	3
Fremont–T13N, R5W		
Oak, White Pine, small amounts of Sugar Maple, Beech, Hemlock	6549	70
Elm, Ash, Red Maple, Swamp White Oak, Tamarack	2110	23
Oak, White Pine, Aspen, Red Maple	410	4
Sugar Maple, Basswood, Elm, Ash, some Hemlock, White Pine	259	3


ISABELLA COUNTY
AND STUDY AREAS
(NOT TO SCALE)
MICHIGAN
9.6 km
N
R 6W
R 5W
R 4W
R 3W
T 16N
T 15N
T 14N
T 13N
9
7
3
1
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7
5
1
3
3
1
3
7
5

Fig. 2. Location of four study areas in Isabella County showing their relationship to the nine presettlement forest types: 1. White and Norway Pine, Oak, Mixed Aspen, Spruce, Fir, Cedar. 2. Elm, Ash, Red Maple, Yellow Birch, White Pine, Spruce, Hemlock. 3. Oak, White Pine, Aspen, Red Maple. 4. Silver or Red Maple, Elm, Ash, some Hemlock, White Pine. 5. Sugar Maple, Basswood, Elm, Ash, some Hemlock, White Pine. 6. Elm, Silver Maple, Ash, Swamp White Oak, Basswood, Cottonwood. 7. Elm, Ash, Red Maple, Swamp White Oak, Aspen, Tamarack. 8. Oak, White Pine, small amounts of Sugar Maple, Beech, Hemlock. 9. Norway, Jack, White pines.

forest type in the four study areas. Table 2 lists the area and percent of the four habitat types as measured from the 1958, 1965, and 1972 photographs. The results show that Chippewa Township had the greatest acreage of old field, Vernon Township was primarily farmland, and Sherman Township had the largest amount of the forested lands.

PRESETTLEMENT VEGETATION AND ITS CHANGES TO 1958. The inherent problem in any discussion of presettlement forests in central Michigan is the difficulty in determining precise limits of forest types due to shifts in community structure at this latitude. Until systematic studies of pollen from lake sediments have been made and correlated with witness tree records to give a more accurate picture of the presettlement forest distribution, the use of Veatch's map (1959) based on soil types must suffice for forest description.

Chippewa Township (T14N, R3W). Of the four presettlement vegetational types found in Chippewa Township, the most extensive was the elm, silver maple (*Acer saccharinum*), ash, swamp white oak (*Quercus bicolor*) forest which covered 4186 ha (45%) in the western part of the township. By 1958, 3363 ha had been converted to farmland (79%). Only 406 ha (10%) of woodland were allowed to regenerate, while the remaining 423 ha were divided almost equally between old field (5%) and unclassified (6%) habitats. The second major presettlement forest was the northern, conifer-deciduous swamp type. White (*Pinus strobus*) and Norway pine (*P. resinosa*), spruce, fir, cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), mixed aspen, and red

TABLE 2. The area (in hectares) and percent of four post-settlement habitat types in the townships.

	Old Field	Farm and Residential Land	Maturing Woods	Other
Year	ha/%	ha/%	ha/%	ha/%
Vernon–T16N, R4W				
1958	182/1.97	7855/85.2	842/9.1	336/3.6
1965	146/1.6	8072/87.6	781/8.5	216/2.3
1972	126/1.4	8049/87.0	806/8.8	233/2.5
Sherman–T15N, R6W				
1958	340/3.7	4533/49.1	3117/33.8	1224/13.3
1965	212/2.3	4148/45.0	3407/36.9	1448/15.7
1972	138/1.5	4570/49.6	3094/33.6	1413/15.3
Fremont–T13N, R5W				
1958	176/1.9	7268/78.9	1614/17.5	158/1.7
1965	201/2.2	6840/74.2	1823/19.8	350/3.8
1972	186/2.0	6636/72.0	1968/21.4	425/4.6
Chippewa–T14N, R3W				
1958	822/8.9	5579/60.5	2096/23.0	699/7.6
1965	724/7.8	5294/57.4	2700/29.2	498/5.4
1972	597/6.5	5056/54.8	2777/30.0	785/8.5

maple (*Acer rubrum*) predominated and were located in the southeastern 2937 ha (31%) of the township. In 1958, 42% of this presettlement forest was mixed aspen woods. Farmland (27%) and old field (17%) were the next dominant types, and there was 14% of unclassified habitats. Two other small areas of presettlement vegetation were located in the southwestern and northeastern corners of Chippewa Township. The southwestern forest (1345 ha) of elm, ash and soft maples was similar to that in central portions of the county, only less well drained. The 1958 data showed this corner to be 89% farmed, 6% maturing woodlands, and 5% old field and unclassified habitats. In the northeastern 860 ha along the Chippewa River, the presettlement vegetation was oak, white pine, aspen, and red maple. The 1958 aerial photographs show 46% maturing woodland, much of it still oak, red maple and aspen, 30% farmed, and almost identical amounts of old field (119 ha) and unclassified habitats (115 ha).

Vernon Township (T16N, R4W). Most of the presettlement vegetation (8547 ha) in Vernon Township was the transitional deciduous-conifer type. Primarily sugar maple (*Acer saccharum*), basswood (*Tilia americana*), elm, and white ash (*Fraxinus americana*), with some hemlock (*Tsuga canadensis*) and white pine, were present; in 1958 all but 16% was farmland. Beech-maple woodlots dominated (10%) the maturing woodland habitat types, while 4% was unclassified and 2% old field. The other two presettlement vegetation types comprised only 781 ha of the township. The southeastern 520 ha were similar to the majority of the township but less well drained. The forest type which also occurred in the southwestern corner of Chippewa Township was dominated by elm, ash, and red maple. The 1958 aerial photograph data showed that 92% of this area was farmed. The oak-white pine forest (261 ha) was located in the northwestern corner of Vernon Township. In 1958, 52% was farmed, 36% was wooded (oak-aspen), and 12% was either old field or unclassified habitat.

Sherman Township (T15N, R6W). Two forest types dominated the presettlement vegetation and almost equally divided the township into east and west halves. In the eastern portion were 5087 ha of oak, white pine, aspen, and red maple, a composition similar to that of Chippewa Township's northeastern section. Recent data show 44% being farmed. The aspen-oak forest type (32%) was regenerated, while 19% was unclassified and 5% was old field. In the western portion the 4146 ha of oak-white pine forests were replaced by agricultural land (57%), aspen-oak woods (33%), old field (2%), and 10% unclassified habitats by 1958. The northeastern 181 ha were swamp species such as elm, ash, red maple, and swamp white oak during presettlement times. The 1958 data shows 75% of this area was farmed, while 25% remained as swamp.

Fremont Township (T13N, R5W). The oak-white pine forests found in Sherman Township's western half extended south and eastward and was dominant (6549 ha) in Fremont Township. More of this vegetation type was being farmed during 1958 in Fremont Township (81%) than in Sherman Township. Only 16% was forested, and 3% was old field or unclassified habitats. The other major forest (2110 ha) was a swamp type comprised mainly of elm, ash, red maple, swamp white oak, and tamarack which extended from north to south along a Pleistocene drainage pathway in the township's center. By 1958, 61% was farmed while in the remaining 29% many swamp species were still present with the introduction of cedar to the presettlement types. A 410 ha extension of the oak-white pine-aspen-red maple presettlement forest found in Sherman Township's eastern portion was located in Fremont Township's southwestern corner. A larger proportion (67%) of this forest type was also being farmed in 1958 than in Sherman Township. Twenty-six percent was woodland with 8% old field and unclassified habitats. The 259 ha located along the western border of Freemont Township was the sugar maple-basswood-elm-ash presettlement forest type, 88% of which was under cultivation in 1958.

A major factor affecting the presettlement forest type and resulting 1958 habitat distribution is soil type. Veatch (1959) based his presettlement map upon soil patterns, and Paterson (1976) pointed out a numerical similarity in 1958 between the percentage of good agricultural soil and farm land. The soils which could not economically support crops had been abandoned and were at a stage between old field and mature woods depending on the length of abandonment.

FOURTEEN YEARS OF SUCCESSIONAL CHANGE IN THE FOUR HABITAT TYPES.

Figure 3 graphically compares the rate of change in habitats among the four townships. There was a net decrease of 924 ha of farmland in the townships. Although the amount of agricultural land in Sherman Township fluctuated over the 14-year period, the total area remained constant. Vernon Township had a slight increase in the amount of farmland. The major reductions came in Chippewa and Fremont Townships, each decreasing at about 40 ha per year.

Between 1958 and 1972 woodlands gained 976 ha, primarily in Chippewa and Fremont Townships. Most of the increase (614 ha) was between 1958 and 1965 in Chippewa Township with only 77 ha added between 1965 and 1972. Fremont Township had a steady 25 ha per year increase for the 14 years. Sherman Township fluctuated and showed a slight decrease, while Vernon Township had little effect on the woodland total.

Amounts of old field were decreasing at an average rate of 11 ha per year in three townships, with the greatest reduction (16 ha/year) in Chippewa Township. Freemont Township showed a slow but steady (0.4 ha/year) increase.

Unclassified habitats showed a 449 ha net gain over the 14 years studied. Only in Vernon Township were the unclassified habitats reduced. The major increases occurred between 1958 and 1965 in Sherman and Fremont Townships. In Sherman Township the impoundment of the Chippewa River to form Lake Isabella was responsible for an increase. Woods being cut for pulp was the probable cause of the increase of unclassified habitats in Fremont Township, and aspen regeneration in Chippewa Township resulted in a possible decrease (29 ha/year) between 1958 and 1965. The regenerated woods in Chippewa Township were cut between 1965 and 1972 accounting for the turn around in land use; however, this resulted in a small net change.

Rate of habitat change, as determined from aerial photographic data, can be attributed to man's activity with the natural plant succession a secondary factor. Man primarily influences succession through his agricultural practices. Although the amount of farmland is actually decreasing because of improved methods, Darlington (1945) predicted that land drainage and agri-

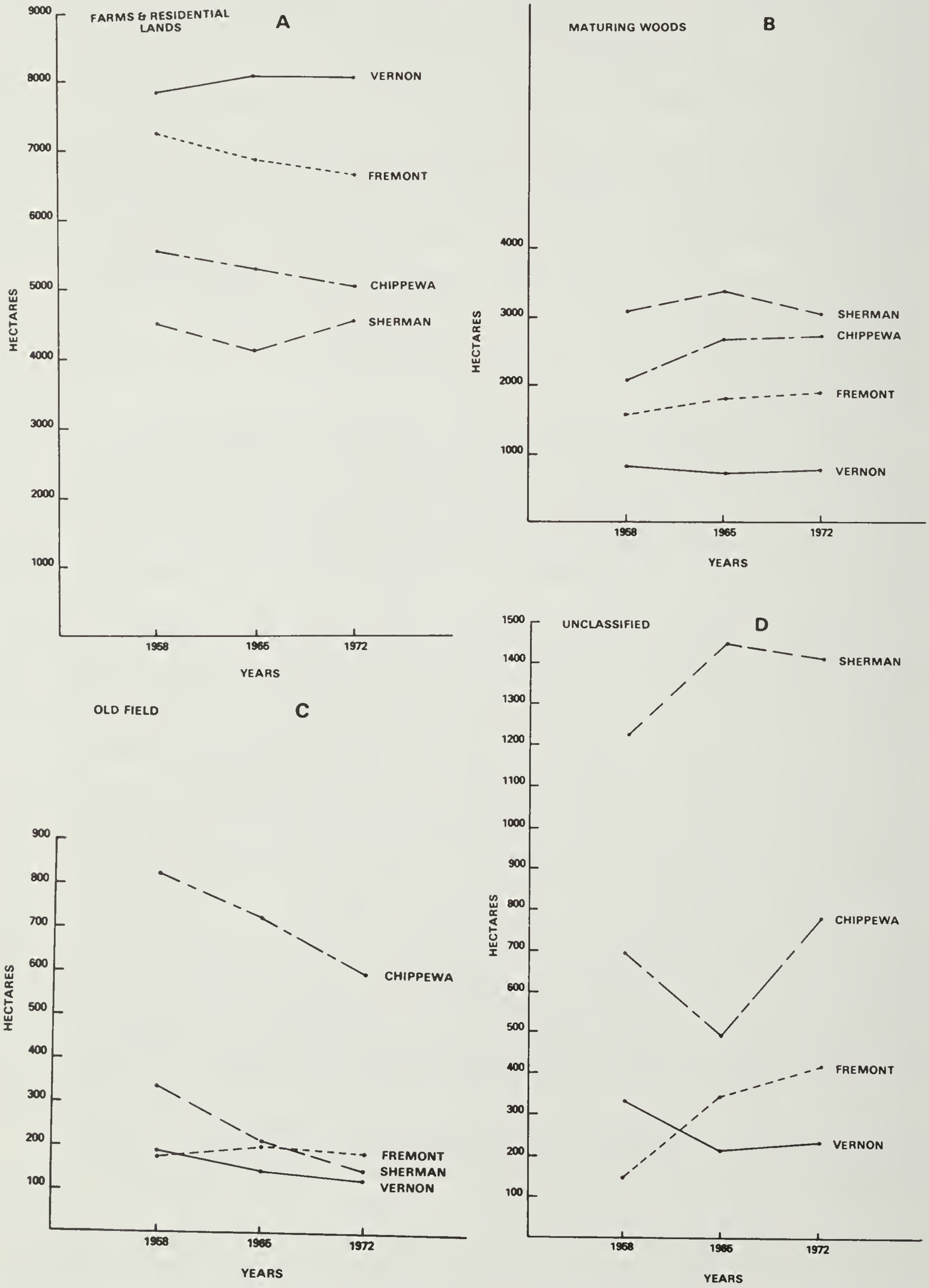

Fig. 3. Comparison of the rate of change of each habitat type in the four study areas. The rate of change is the slope of the lines.

cultural practices would lead to new plant populations better suited to the changed environment and that these changes would continue indefinitely. Webb (1973) has contrastingly demonstrated that the trend is toward the regeneration of native forest habitats. Therefore, man's activities have only reduced the amount of forested land but not changed its basic character.

At the present time farmland reduction has resulted in an increase in abandoned areas. Shrubby old field habitats are being closed in by tree species more rapidly than similar shrubs are invading recently abandoned areas. The inclusion of a few secondary successional species such as cedar and aspen along with the insignificant regeneration of white pine are the major deviations from presettlement forests in the county.

From these data one might be optimistic as to the fate of native habitats in Isabella County. Because of technological advances land is returning to the original successional patterns. The amounts of most habitat types are not drastically changing, and so the diversity of native game and non-game animal populations, which depend upon the native plant populations, should be remaining constant.

SUMMARY

Presettlement forest distribution was compared to the 1958 location of agricultural land, abandoned land, old field, and maturing woods in Isabella County, Michigan. The data showed the recent land use patterns of the presettlement forests and indicated no major change in the species composition of the regenerating woods. Aerial photographic analysis indicated that the fluctuating amounts of habitat are actually becoming forested lands. Man's increased farming technology was proposed as an explanation for the forest regeneration and its positive effect on native animal populations was also suggested.

I thank R. E. Bailey and G. S. Starks for critically reviewing the manuscript. The aerial photographs were lent to me by the Isabella County Agricultural Stabilization and Conservation Service office of the U.S. Dept. of Agriculture. The data presented here were obtained during research for a master's degree at Central Michigan University.

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REVIEW

NORTHLAND WILD FLOWERS. A Guide for the Minnesota Region. By John B. Moyle & Evelyn W. Moyle. University of Minnesota Press, Minneapolis. 1977. 236 pp. $12.95.

In many ways this is a model of what a local wildflower guide should be. There are color photographs showing typical habitats and 300 native and naturalized species (some in two seasons), descriptions of various regions in Minnesota with places to go for wildflowers, suggestions on blooming seasons, much information on Indian (Chippewa) uses of wild plants, and a brief summary of "official interest" in the Minnesota flora with special reference to conservation measures. The brief descriptions of the species illustrated (plus about 100 others) appear original and not merely compiled from manuals. The occurrence of each species in Minnesota and beyond is indicated. The text is clearly and concisely written and often adds interesting notes on the origins of common names, Indian lore, and other topics.

The color photos have evidently suffered somewhat in printing. For the most part, they are well composed to show the natural habit of the plant in a way appropriate for such a guide (not artificially "posed"), but too often they appear dulled or somewhat washed out, as if black had been omitted in the printing. The picture of *Polygonum cilinode* is upside down.

The work seems reasonably free of typographical errors (I noted barely a dozen) and of questionable statements. Botanists who know our species of pitcher-plant in Florida and Mississippi will be surprised to read that it only ranges "south to northern U.S." and it is misleading to list (p. 9) columbine under "irregular flowers" when in fact they are radially symmetrical.

For identification by the layman, this guide should be very helfpul as far "east" as Michigan, although there is a larger representation of prairie plants in Minnesota. The glossary is weak, often defining an adjective as a noun and unnecessarily restricting the application of some words: why is a haustorium only in dodder and not other parasites? why an involucre only in Composites? why a midrib only in pinnately veined leaves (hence, e.g., no monocots)? I have no objection to simplifying definitions for non-professionals, but it would be no more technical, and somewhat more precise, to say that a panicle is a *branched* inflorescence rather than a "loose" one. Although the word is used in the text, there is no definition of "pistil" (nor of ovary or any other term for parts of the gynoecium). No diagram of a "typical" flower helps with the terminology. A number of useful references are listed, but the coverage seems a bit spotty and outdated. Fassett's excellent spring flora of Wisconsin is not listed under "Regional" works, nor is anything pertaining to Michigan even though Isle Royale is adjacent to Minnesota and is mentioned several times. A 1933 work by Stevens is listed but not his later "Handbook of North Dakota Plants." The 1947 reprinting of the 1935 "Flore Laurentienne" is listed but not the newer 1964 edition. Similarly, the original 1966 edition of Morley's spring flora of Minnesota is listed, not the revised 1969 edition. And there is no reference to the 1969 revision and republication of the key and illustrations from the excellent 1945 Moyle and Hotchkiss work on aquatic and marsh vegetation of Minnesota. Moyle's own 1964 work is entitled "Northern Non-woody Plants," not "Minnesota Non-woody Plants" as listed. Tryon's name is consistently misspelled, and Kingsbury comes out Kingsburg in one place and Kingsley in another.

E. G. Voss

DAVID BATES DOUGLASS' PLANTS FROM THE CASS EXPEDITION IN THE SCHWEINITZ HERBARIUM

Ronald L. Stuckey
Department of Botany, College of Biological Sciences
Ohio State University, Columbus, 43210

In November 1819, Lewis Cass, then Governor of the Michigan Territory, proposed to the Secretary of War, the Honorable John C. Calhoun, that an expedition be conducted to explore more thoroughly the Lake Superior and Upper Mississippi region. With the support and encouragement of President Monroe, the objectives were to provide for frontier defense, enhance and promote fur trade, and gain a more detailed knowledge of the region with respect to topography, mineral deposits, and natural resources. To carry out the latter objective, Secretary Calhoun appointed Captain David Bates Douglas (1790-1849), Assistant Professor of Natural Philosophy in the United States military academy at West Point, to prepare a map and to study botany by making collections of plants. The Cass Expedition, which hoped to reach the source of the Mississippi River, was conducted during the summer of 1820, leaving Detroit on 24 May and returning there on 23 September. During the course of the expedition Douglass obtained plant specimens. This paper considers those plants that were sent to Lewis David von Schweinitz, the Moravian clergyman and botanist then living in Salem, North Carolina. They reside today in his vast herbarium (incorporated in the herbarium of the Academy of Natural Sciences, Philadelphia).

Captain Douglass was under obligation to the War Department and to Governor Cass to report the results of his findings on the expedition. In writing to the editor of *The Medical Repository*, New York City, Douglass said (10 July 1821):

> I am engaged in preparing for publication a Map and Geographical Memoir on the N.W. to be accompanied with the scientific results generally of the expedition. It will contain of course some chapters on the Natural History and in the composition then I shall stand in need of all the aid which I can have any right to hope for from my scientific friends in N. York that anything like a systematic account should be given can hardly be expected considering how little has been known heretofore, and how cursory our observations must have been. Yet it may be profitable to present a brief view of such discoveries as have been made either by ourselves or by former travelers in this Department. . . . Dr. Torrey who has my botanical collections will furnish me some notices for that branch. . . . The map will be of good size and there are proposed to be a number of engravings besides . . .

In a letter to Dr. John Torrey (10 July 1821), a young physician and active botanist of New York City, Douglass also discussed his intention to publish a major treatise including a chapter on the vegetable productions of the Northwest. For such a purpose, he had provided himself with notes on the forests of all the districts through which the expedition passed. Douglass also encouraged Dr. Torrey to publish a systematic account of the plants collected so as to make the botanical observations on specific plants available immediately. Douglass had left the collection in New York City some time earlier in

1821, and Torrey's notice of 113 plants with appropriate annotations appeared in Silliman's Journal later that year (Torrey, 1821). Accompanying the article was an explanatory and apologetic letter Douglass wrote to the editor stating that he was not a professed botanist and the conditions in the country traversed by the expedition were not particularly desirable for plant collecting. In addition, part of the collection was injured by accident on the Wisconsin River, where his canoe became filled with water and soaked the dried plants to an extent that they were completely spoiled before they could be redried.

Upon his return to West Point, Douglass had new academic responsibilities and heavier family obligations because of the death of his father-in-law. Consequently, he never completed the topographic map and projected scientific work. Until recently, the only account of the botanical results of the expedition was in Torrey's published paper of 1821. In 1969, the journal of David Bates Douglass, having been in the custody of his descendants, was published under the title, *American Voyageur*, edited by Jackman and Freeman with the assistance of Rickard and Carter (1969). Throughout the journal, brief references to the vegetation and notations of those days when Douglass botanized are recorded. With the publication of Douglass' journal, it appeared that it might now be possible to correlate data from the journal with the plant specimens to gain a more complete picture of the botanical results.

The plants which Douglass collected on the expedition are to be sought in Torrey's herbarium, which is incorporated in the herbarium of the New York Botanical Garden. What has generally not been known, however, is that Torrey sent some of these plants to Schweinitz, even though Rodgers (1942, p. 65) has written a one-sentence note to that effect. Torrey's correspondence with Schweinitz, the "dean" of American botanists, began in December 1819, and soon thereafter they began an exchange of plants (Shear & Stevens, 1921). In a letter dated 13 October 1921, published erroneously under the date 12 October 1821 by Shear and Stevens (1921, pp. 150-152), Torrey described six different collections each containing a number of dried plants he was sending to Schweinitz. Of the fifth collection (composed of flowering plants) he said:

> The Phenogamous plants are principally from the northern States, with the exception of a few collected by Prof. Douglass in the late expedition of Gov. Cass to the sources of the Mississippi. The whole collection was presented to me & a Catalogue of it will appear in the next No. of [Silliman's] [1] Journal.

Included in this notation is a list of 57 plants, most of them with names, and a few have additional brief descriptive notes. The plant list is in the original letter but was not included in the published version. Since Torrey stated that only a few of the plants were from the Cass Expedition, I compared the names in this list with those published by Torrey (1821) and determined that 14 were common to both lists and that possibly these specimens then were therefore originally from Douglass.

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[1] The letter is torn at this position and the word is missing.

Attempting to locate these specimens in Schweinitz's herbarium becomes problematical because of the manner in which Schweinitz treated the specimens that he secured from his distinguished contributors. Pennell (1935) and Stuckey (1967, 1971) have discussed in detail how Schweinitz usually discarded the original labels and left his own cryptic notes by writing the name of the donor and/or locality alongside the specimen on the paper to which the plant was mounted. A record of most of Schweinitz's specimens is contained in the unpublished catalogue of his herbarium (Schweinitz, undated). The present attempt has been to correlate data from Torrey's paper of 1821 and letter of 13 October 1821, Schweinitz's herbarium catalogue and the surviving specimens in his herbarium, and Douglass' journal to gain a better idea of the information available for the plants collected on the Cass Expedition. A list of the plants and their associated data and annotations is presented at the end of this paper.

Of the 14 plant names listed in Torrey's letter, all of them are noted in Schweinitz's herbarium catalogue, but only six of them are identified specifically with Douglass or the Cass Expedition. Specimens of eight of these taxa were located, and in some cases the original label with Torrey's handwriting was intact; in other cases the handwriting was that of Schweinitz or of Charles Pickering, who was curator of the Academy's herbarium from 1827 to 1838 (Pennell, 1942) during the time when Schweinitz's herbarium was bequeathed to the Academy. No information from any of the manuscript or specimen sources was located for *Dracena borealis (Clintonia), Populus balsamifera, P. tremuloides,* or *Streptopus roseus*, and specimens of *Arbutus uva-ursi (Arctostaphylos)* and *Potentilla anserina* could not be located even though they were noted in Schweinitz's herbarium catalogue. Correlating these data with the recently published account of Douglass' Journal (Jackman *et al.*, 1961) becomes somewhat difficult because Douglass, not being trained as a botanist, did not know the names or affinities of many of the plants. He did, however, seem rather consistent in noting the days when he botanized. Correlating these days with data from the herbarium and manuscript sources, I have arrived at the probable time and place where each specimen was collected. This information is presented in the parenthetical phrase following data on each specimen. Determinations of the specimens are also provided in bold-face type, if the name is now different from that under which the specimen was published.

In Torrey's account of Douglass' plants, he described five taxa as new to science. These are *Andromeda polifolia β rosmarinifolia, Arabis rhomboidea β purpurea, Panicum longisetum, Trientalis europaea β angustifolia,* and *Vicia douglassii.* Specimens of the *Arabis* and *Panicum* were sent to Schweinitz and constitute duplicate type material which fact has now been designated on the specimens.

The information concerning the type locality of *Arabis rhomboidea* Pers. *β purpurea* Torrey [*Cardamine douglassii* Britt.] is indeed of interest. When Torrey originally described the taxon, he did not list a locality, and neither did Britton, who first published the name *C. douglassii* based on Torrey's description (Stuckey, 1962). The combination of all the data from the several sources now assembled reveals that the type locality is probably Buffalo, New

York, where Douglass wrote in his journal on 2 May that while there he "botanized." It is the first place in his journal that he mentions botanizing. In his herbarium catalogue, Schweinitz provided the additional note, "Buffalo New Yr." How Schweinitz learned of this locality information is not known, but Torrey could have told him verbally at some later date. The complete entry for this species in Schweinitz's herbarium catalogue was written at a much later date (sometime in 1831 or after) because of the large complex number given to the taxon and writing it in black ink with a finer pen point than the earlier entries in faded brown ink, a procedure that has been described elsewhere (Stuckey, 1967). The data from the several sources, however, are reliable and consistent. The species usually flowers from mid-April to early May in the northern part of its range. It is doubtful that Douglass would have collected a flowering specimen of this species on the expedition after arriving in Detroit on 8 May. Neither does Douglass make any mention of finding such a plant in the Detroit area. In the *Flora of North America,* Torrey and Gray (1838-1843, p. 83) listed five localities for this taxon, but only one, "Western part of the state of New York!" can represent the locality where Douglass obtained the plant.

As a unit, these few specimens in the Schweinitz herbarium documenting the botanical information of the Cass Expedition are extremely fragmentary. At most one small plant or portion of each plant is preserved. The published account by Torrey does mention some of the distinctive Great Lakes shoreline plants, including *Iris lacustris, Primula farinosa (P. mistassinica),* and *Potentilla anserina*, which are of interest for their rarity and/or localized distribution in specific habitats.

DOUGLASS' COLLECTIONS IN THE SCHWEINITZ HERBARIUM TYPE COLLECTIONS

p. 32. *Arabis rhomboidea* Per. *β purpurea* Torrey Spring Cress
= **Cardamine douglassii** Britt., *fide* R. L. Stuckey. 1962. Mich. Bot. 1:32.
No locality given.
Torrey's letter: Noted as "Tetradynamous plant found by Prof. Douglass."
Schweinitz's catalogue: Cardamine, p. 143, No. 1117/19067-12986-28. "*Cardamine Douglassii* Tor. (Arabis) / Buffalo New Yr."
Specimen: "Arabis (purple flowers) / probably a variety of A. rhomboidea / root tuberous-granulated." Handwriting of John Torrey. (Probably obtained 2 May, Buffalo, Erie County, N.Y.) Det. **Cardamine douglassii** Britt.

p. 58. *Panicum longisetum* Torrey Walter's Millet
= **Echinochloa walteri** (Pursh) Heller f. **laevigata** Wiegand, *fide* A. S. Hitchcock & A. Chase. 1950. Man. Grasses, p. 860.
"On the banks of the Fox River, &c. August."
Torrey's letter: Noted with name and asterisk, the asterisk indicating a new species.
Schweinitz's catalogue: Setaria, p. 32, No. 171/1219-13. "Setaria longisetum Torrey / Fox river / Douglass / Exped. of Gov. Cass."
Specimen: "(herb Schw) / sub nom Panicum (as Setaria) longisetum / Fox river / Douglas[s] cum Cass / Dr. Torrey.'" Handwriting of Charles Pickering. (Obtained 14-20 August, Wisconsin.) Det. **Echinochloa walteri** (Pursh) Heller.

OTHER COLLECTIONS

p. 62. *Arbutus uva-ursi* L. Kinni-kinick

No locality given.

Torrey's letter: Noted with name only.

Schweinitz's catalogue: Arctostaphylos, p. 100, No. 754/4812-1. "Arctostaphylos uvaursi/ . . . Prof Douglass / Lakes."

Specimen: Not located.

The common name, "kinni-kinick," was reported by Torrey (1821, p. 62), who explained that the plant was "smoked by the Indians as a substitute for tobacco." It is not *Chimaphila maculata* as footnoted by Jackman *et al.* (1969, p. 80). Henry Rowe Schoolcraft (1821, pp. 161, 215), mineralogist on the expedition, wrote in his journal that the kinni-kinick was first noticed on 23 June when the expedition was at the mouth of the Huron River in Baraga County, in the Upper Peninsula of Michigan, and later on 13 July near Sandy Lake in Aitkin County, Minn. Douglass did not mention the plant until the party reached Sandy Lake and noted it under date of 15 July (Jackman *et al.*, 1969, p. 80).

p. 58. *Atheropogon oligostachyum* Nutt. Mesquite-Grass, Grama-Grass

". . . in abundance on the Mississippi above Sandy Lake."

Torrey's letter: Noted with name only.

Schweinitz's catalogue: Atheropogon, p. 30, No. 161/1168-1. "Atheropogon oligostachys [sic] / Nuttall / Missouri." The information in the catalogue does not agree with that on the specimen.

Specimen: "Antheropogon [sic] oligostachyum Nutt. Gen. / Found by Capt. Douglass during Cass's exped^{n} to the sources of the Mississippi." Handwriting of John Torrey. (Probably obtained 18 July, Aitkin Co., Minnesota.) Det. **Bouteloua gracilis (HBK.) Lang. ex Steud.**

p. 65. *Hyssopus anisatus* Nutt. Giant Hyssop

"Savannah Portage. July."

Torrey's letter: Noted with name only.

Schweinitz's catalogue: Hyssopus, p. 131, No. 987/6564-6. "Hyssopus anisatus / Savannah Portage / Sources of Missi[ssi]ppi / Douglas[s] / Torrey / (Stachys foeniculatum)."

Specimen: "Hyssopus anisatus / Savannah Portage / Prof Douglass / Torrey." Handwriting of Schweinitz. (Probably obtained 13 or 14 July, Aitkin Co., Minn.) Det. **Agastache foeniculum (Pursh) Ktze.** by Harold Lint, 1941.

p. 57. *Iris lacustris* Nutt. Dwarf Lake Iris

". . . on the gravelly shores of the Islands of Lake Huron."

Torrey's Letter: Noted with name only.

Schweinitz's Catalogue: Iris, p. 15, No. 15/590-19. "Iris lacustris / Huron / Douglass / . . ."

Specimen: "Iris lacustris / Shores of Lake Huron / Douglass / Torrey." Handwriting of Schweinitz. (Obtained 27 May–13 June, Michigan.)

p. 65. *Linnaea borealis* L. Twinflower

"Near White Fish Pt. Lake Superior, June 19th."

Torrey's letter: Noted with name only.

Schweinitz's catalogue: Linnaea, p. 139, No. 1074/7077-1. "Linnaea borealis . . ." Schweinitz did not note any specimens from Lake Superior.

Specimen: " 'Torrey' (herb Schw)." Handwriting of Charles Pickering. (Obtained in Chippewa Co., Mich.)

p. 66. *Petalostemum villosum* Nutt. Silky Prairie-clover

"Grows with the preceding species." "Prairies of the Upper Mississippi, below Sandy Lake."

Torrey's letter: Noted with name only.
Schweinitz's catalogue: Petalostemum, p. 170, No. 1261/9038-1. "Petalostemum villosum / Missi[ssi]ppi / Douglass."
Specimen: "Herb. Schweinitz / Petalostemum villosum / Mississip[p]i / Prairies / Douglass / Torrey." Handwriting of Schweinitz. (Probably obtained 27 July, Crow Wing Co., Minn.)

p. 59. *Primula farinosa* L. Bird's-eye Primrose
"Shores of Lake Huron."
Torrey's letter: Noted with name and locality "Lake Huron."
Schweinitz's catalogue: Primula, pp. 54, No. 327/2321-14. "Primula farinosa . . ." Schweinitz did not note any specimens from Lake Huron.
Specimen: "Lake Huron / Torrey / Douglass." Handwriting of Schweinitz. (Obtained 24 May-6 June, Michigan.) Det. Primula mistassinica Michx.

p. 64. *Potentilla anserina* L. Silverweed
"Near Detroit."
Torrey's letter: Noted with name only.
Schweinitz's catalogue: Potentilla, p. 117, No. 891/5778-9. "Potentilla anserina / . . . Huron / Douglass'
Specimen: Not located.

The research presented here has resulted principally from two extended periods at the Academy of Natural Sciences, Philadelphia, sponsored by a National Science Foundation grant to the Academy in 1973 and by the Academy in 1977.

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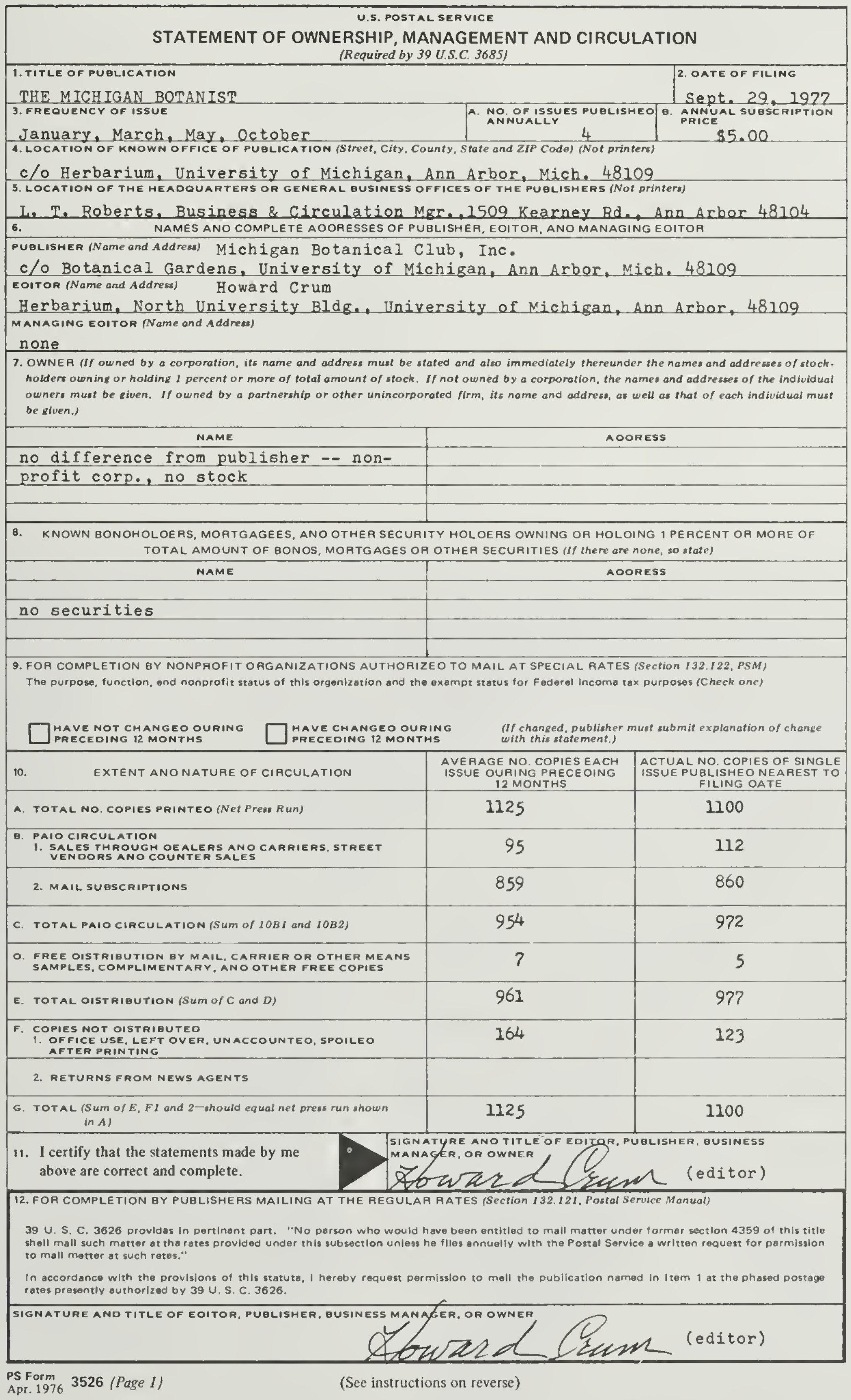

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CONTENTS

Presettlement Forests of the Pine River Watershed (Central Michigan) Based on Original Land Survey Records
Ronald O. Kapp 3

History of Recent Habitat Changes in Central Michigan
Robert L. Paterson, Jr. 15

Review 24

David Bates Douglass' Plants from the Cass Expedition in the Schweinitz Herbarium
Ronald L. Stuckey 25

On the cover: Pilobolus, *the "Hat-Thrower," a dung-growing zygomycete that discharges its black sporangia toward a light source; photo by the late E. B. Mains*

33
17
2

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THE STATUS OF CERTAIN HAWKWEEDS (HIERACIUM SUBGENUS PILOSELLA) IN MICHIGAN

Edward G. Voss and Mark W. Böhlke
Herbarium, University of Michigan, Ann Arbor, 48109

Among our best known, most colorful—and often most obnoxious—weeds are the yellow-headed and orange-headed hawkweeds which brighten roadsides and old fields in early summer. They first appeared in Michigan relatively recently, compared with most of our common weeds, but they have been conspicuously successful in getting established. The yellow-flowered plants have long presented taxonomic and nomenclatural problems: even if we knew where and how to separate species, we would not be sure what names to use for them. Hybrids between the common species have only recently been noted in the state. In the same subgenus, two additional species (distinguished from the common ones by their fewer and larger heads) occur rarely, and the time seems right for a review of past and present information on the distribution of *Hieracium* subgenus *Pilosella* in Michigan. This background and summary of where we stand may lead some ambitious person to investigate further the reproductive behavior and taxonomic identity of plants too common to be further ignored.

Hawkweeds have traditionally been scorned rather like the weather. Everyone talks about them, but no one can *do* much about them. Fernald (1950, p. 1562) considered his treatment in *Gray's Manual* to be tentative "until a rational presentation of European species is available." In Vol. 4 of *Flora Europaea,* Sell & West (1976) gave what is undoubtedly the most rational presentation thus far for the European taxa. In the meantime, some other treatments relevant to the local region appeared: Cronquist in Gleason (1952) for northeastern United States and adjacent Canada; Johnson & Iltis (1964) for Wisconsin; Lepage (1971) for Quebec.

The species of *Hieracium* subgenus *Pilosella*—by the splitters considered deserving of separate generic status as *Pilosella* (Sell & West, 1974)—are readily recognized in this region by having leaves all or almost all basal; in subgenus *Hieracium,* the leaves are cauline (except for the distinctive *H. venosum*). Only in *Pilosella* do stoloniferous species occur. The principal problem with this subgenus in our area is determining how many yellow-flowered species we have, and what to call them. Unfortunately, the treatments cited above are far from being in agreement as to what species exist and what characters to employ in distinguishing them. They do agree in that none of them clearly accommodates Michigan specimens.

Sell & West (1974 & 1976) clarified the reproductive situation in *Hieracium* by noting that in subgenus *Hieracium* only a few species are sexual and apomixis is the rule, whereas in subgenus *Pilosella* the species are sexual or only partly apomictic and hybrids are numerous. In 1975 they stated of subgenus *Pilosella*: "Plants intermediate in character occur between most species and subspecies."

KING DEVIL IN MICHIGAN

From the key and descriptions by Sell & West (1976), the following distinctions summarize the essential differences between the tall yellow-flowered species ("King Devil") which we might have in Michigan:

1. Stem and leaves with numerous simple hairs (glandular or eglandular); involucres (5) 7-9 mm long *H. caespitosum [H. pratense]*
1. Stem and leaves glabrous or with scattered (often long), simple, eglandular hairs
   2. Peduncles with at most a few stellate hairs; involucres 5-7 mm long *H. piloselloides [H. florentinum]*
   2. Peduncles with ± dense stellate hairs; involucres 5-8.5 mm long *H. praealtum*

Sell & West treated *H. floribundum* (a species in Fernald, Cronquist in Gleason, and Lepage) as a hybrid between *H. caespitosum* and *H. lactucella,* differing from the former "in its glaucous leaves, and from *H. lactucella* in its taller habit." (*H. lactucella* is not considered to be established on this side of the Atlantic.)

Lepage treated *H. praealtum* as only a "group" within *H. piloselloides,* and distinguished it on the basis of rather large, pale phyllary margins instead of stellate-pubescent peduncles. Cronquist ignored *H. praealtum* completely; but Fernald, who distinguished it on rhizome and stolon characters, referred to it as "Locally abundant . . . Nfld. to N.Y." Johnson & Iltis said that *H. caespitosum* has "rhizomes lacking or inconspicuous," while Fernald said that this species (as *H. pratense*) has "rhizomes slender and cord-like."

The presence or absence of stolons is often given as a major (or the only) character to distinguish certain taxa. However, Sell & West (1975, p. 260) have observed that "presence or absence of stolons is not a very reliable character"—only in part because they are so seldom collected. In plants they referred to *H. floribundum,* Thomas & Dale (1974) noted that stolon production per flowering plant is curtailed at high densities (a means of self-regulation of the population). In their 1976 treatment, Sell & West noted that in *H. piloselloides* stolons are "usually absent, slender when present"; in the various subspecies of *H. praealtum* they range from "absent or very short" to "long and slender"; and in *H. caespitosum* they are "usually underground" in one subspecies and "above ground, obviously leafy" in the others. Guppy (1976) writing of British Columbia plants, admitted that "a good case could be made" for considering *H. floribundum* and *H. caespitosum* as different phases of a single species, which is "closely related to *H. piloselloides*" but differs in being stoloniferous.

Confronted by such an array of opinions, we boldly attempted to select those which apply to Michigan specimens. A first review stressed the traditional characters of stolons, leaf pubescence (including presence or absence of stellate hairs), and involucre length. In most cases, specimens could not be identified as a particular species. The ambiguity of the characters used to separate the species, the combinations in which they occur, and the degree of overlapping of characters led to serious questions about the separateness of species in this region. Subsequent to this initial review, Volume 4 of *Flora Europaea* appeared, and a new assessment was undertaken, stressing the pubescence characters of Sell & West, with some attention again to involucre size. Our specimens were sorted into five groups, although not without some ambiguities. Size of involucre and density of stellate pubescence on peduncles may vary a great deal on the same plant. Furthermore, involucre length apparently increases as the phyllaries mature until seed sets. Although mature involucres about (6.5)7-8(8.5) mm long were termed "large" and those about (4.5)5-6(6.5) mm were termed "small," no clear discontinuities exist in our material in regard to involucre size, just as no line can be drawn between "numerous" and "scattered" hairs or "few" and "± dense" stellate hairs. The five groups, admitting this clear lack of discontinuity, were as follows:

1. Heads large; peduncles densely stellate-pubescent (usually with some longer, simple, gland-tipped hairs and still longer, simple, eglandular hairs); leaves glabrous above or at most sparsely hairy, apparently ± glaucous. This is one of our commonest combinations of characters, occurring throughout the state.
2. Heads small; plants otherwise as above. Apparently even more often collected than the preceding and likewise throughout the state. Collections of yellow hawkweeds from Houghton County as early as the 1920's include both small- and large-headed plants. Apparently head size has been quite variable ever since these plants were first introduced in the region, and all might be considered as *H. praealtum* sensu Sell & West.

The remaining three groups have relatively few collections each:

3. Heads large; peduncles sparsely stellate-pubescent (but ranging to ± densely so); leaves glabrous or nearly so above, apparently glaucous.
4. Heads small; plants otherwise as in group 3. Almost all specimens referred to groups 3 and 4 were collected in the Upper Peninsula during the past 30 years.
5. Heads large; peduncles densely stellate-pubescent; stems hairy (long simple hairs) and leaves hairy above (many hairs as close together as 1 mm). The leaves in this group are larger–1.2-2.5 cm broad, up to 14(20) cm long–than average for the other groups and are probably not glaucous (although this is difficult to determine from herbarium specimens when labels fail to mention the condition). These plants represent what has been considered to be *H. caespitosum* [*H. pratense*] in this region. A few small-headed plants as in group 2 (from Washtenaw and Oakland counties) have basal leaves rather hairy (as much so, for example, as the least hairy specimens of *H. aurantiacum*), and are doubtfully assigned here also.

It is interesting to note that one or two collections in each of groups 1 to 4 has some indication of a stolon (most specimens in group 5 do). Prostrate stolons as conspicuous as those of *H. pilosella, H. flagellare,* and *H. aurantiacum* are not common in these plants, and they are not apparently correlated with the other characters examined. Secondary flowering stems, curved at the base but ultimately erect, are frequent, especially in group 1. A very few specimens (mostly in group 2) have ascending shoots bearing numerous small leaves (the "erect stolons" of some descriptions?).

Groups 3 and 4 parallel groups 1 and 2, respectively, differing in less dense stellate pubescence on the peduncles, and thus (at least group 4) are perhaps what ought strictly to be called *H. piloselloides* [*H. florentinum*], although some specimens are difficult to categorize as having "dense" or "sparse" pubescence. Categorization of specimens by combinations of simple and stellate pubescence on the leaves is similarly ambiguous, and correlation of pubescence types with geographic distribution in the state is impossible. It should also be noted that color of pubescence (both stellate and simple hairs) is not a useful character, for as noted by Lepage (1971, p. 658) the tawny color develops as a specimen ages and is best seen on the oldest herbarium specimens.

Various hypotheses might explain the absence of clear species distinctions in our yellow-flowered hawkweeds. The different species may exist as described in other regions, but only one exists here and we would be in error trying to make more of it. One species may have been introduced first and one or two others later, with such extensive hybridization resulting that distinctions have been swamped; dates of specimen collections and their geographic distribution would not seem to support this idea. A complex of species and/or hybrids may have moved into the state, already confused before they arrived.

Most Michigan specimens have been called *H. florentinum* All., a name which Sell & West indicated is synonymous with typical *H. piloselloides* Vill., an earlier name. Lepage suggested that *H. florentinum* is a distinct species, the name misapplied to the common weed, which he too called *H. piloselloides* (including *H. praealtum*).[1] The practical solution at present appears to us to be adoption of *H. piloselloides* as the best name for our common yellow hawkweed, at least in a broad sense. Perhaps a very few specimens (group 5 above, and cited below) might be referred to *H. caespitosum* Dumort. (*H. pratense* Tausch).

HISTORY AND DISTRIBUTION OF THE SPECIES IN MICHIGAN

1. **Hieracium pilosella** L. Mouse-Ear Hawkweed (Map 1)

This species is easily recognized by its solitary yellow heads and numerous leafy stolons, the leaves white-felted beneath (tawny in old dried specimens), giving the plants the vegetative aspect of some species of *Antennaria.*

The first report for Michigan was in Beal & Wheeler's "Michigan Flora" (Rep. St. Bd. Agr. Mich. 30:577. 1892), as follows: "Introduced at Benzonia,–G. A. Clark." A supporting specimen (MICH) ex herb. C. K. Dodge bears a label in Dodge's hand which says "Geo. A. Clark, Sept. 1861. Near Benzonia, Benzie Co. Mich." Benzonia was founded in 1858 (see Mich. Bot. 15:65, footnote 91. 1976), and it is interesting that this characteristic weed of grassy places was so early established. The species is now a common lawn weed in Benzonia (Voss 14654 in 1975, MICH, MSC, NY). Darlington (Rep. Mich. Acad. 20:266-267. 1919), in a report on introduced weeds in Michigan, listed this species for the "1881-1904" period and said "occasional in Michigan." Clearly, he assigned the time of introduction on the basis of the date of the Beal & Wheeler published report, not on the actual date of the collection. Benzonia specimens can be assigned to subsp. *trichosoma* Peter, as delimited by Sell & West (1976). Herbarium specimens after two years have retained the white color of the pubescence, but the 1861 specimens have the pubescence deeply tawny, supporting the observation of Lepage on color changes with age in this genus.

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[1] We suspect that the name *H. floribundum* has sometimes been applied to what in other regions has been called *H. florentinum* and sometimes to something else. Myers (1950) had only *H. floribundum* and *H. pratense* in this complex in West Virginia, where most specimens seemed to be "a blend of the typical characters of each species," and he was tempted to recognize "one broad species." On Prince Edward Island, Erskine (1960) recognized *H. floribundum* and *H. pratense,* but like Myers he did not refer to *H. florentinum* or *H. praealtum* at all. Guppy (1976) admitted that "a good case could be made" for considering *H. floribundum* and *H. caespitosum* as different phases of a single species, which is "closely related to *H. piloselloides*" but differs in being stoloniferous.

The only other Michigan record is from a lawn at Cranbrook, Bloomfield Tp., Oakland County (Billington in 1922, BLH), cited by Farwell (Pap. Mich. Acad. 3:109. 1924). No other material was seen by Wolff (1928).

2. **Hieracium flagellare** Willd. (Map 1)

This plant resembles the preceding in its well-developed leafy stolons, but individuals are taller and each main scape bears (in our specimens) 2-3 yellow heads. These are larger (involucre ca 10-11 mm) than in any of our other taxa in this subgenus. Stellate hairs are numerous on the undersides of the leaves, but they do not form a dense felt as in *H. pilosella.*

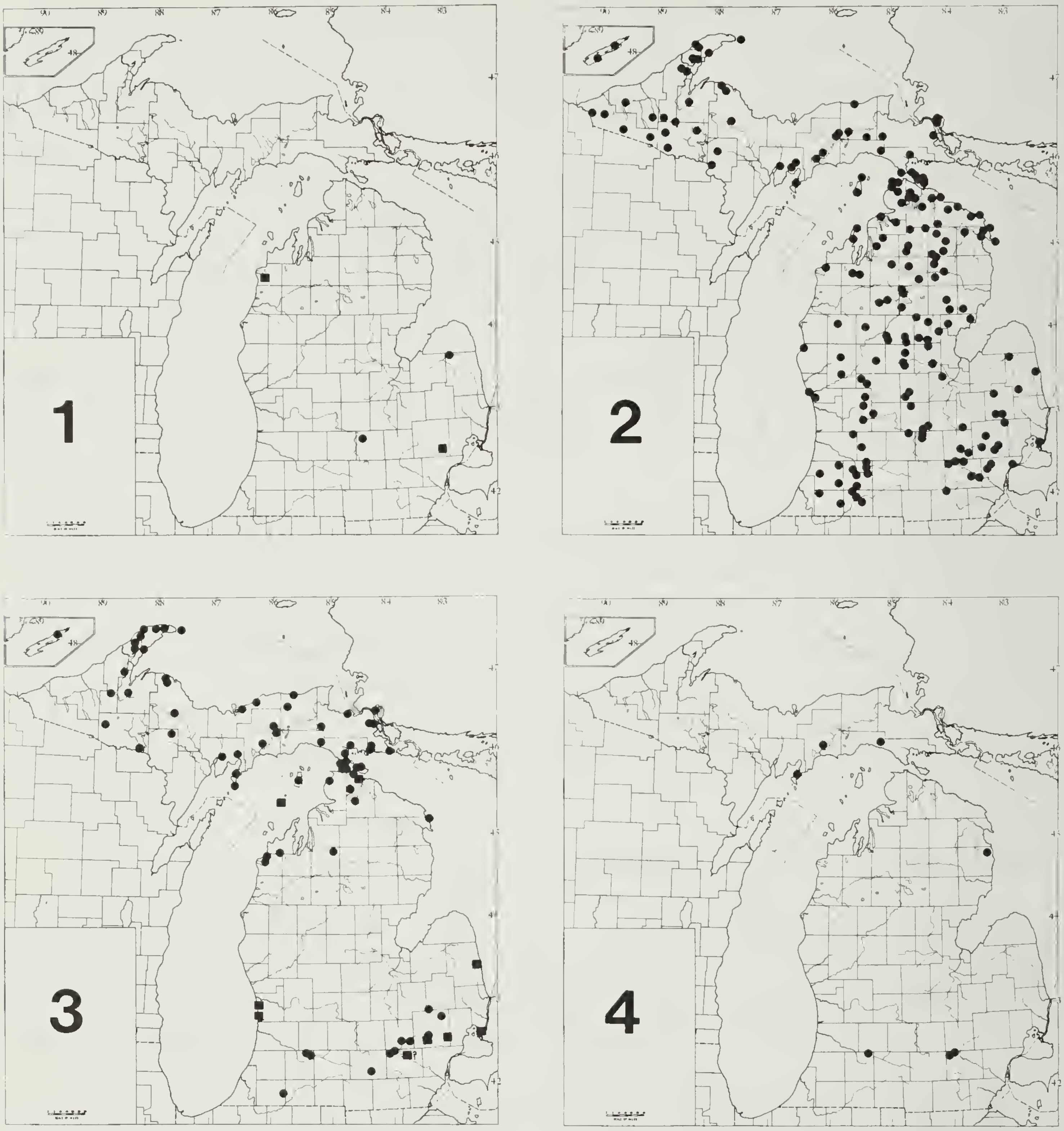
H. flagellare is sometimes treated as a hybrid, *H. caespitosum* X *H. pilosella* (e.g., Lepage, 1967 & 1971); however, since the heads are larger than in either of these species (cf. Sell & West, 1976, p. 369), and its known stations in Michigan are not near those for either of them, such an origin for our plants, at least, seems questionable.

Mentioned for Michigan in *Gray's Manual* (Fernald, 1950), but there are no explicit reports for the state. Two recent collections have been seen: Sanilac Co., sec. 12, T14N, R12E, E side of Germainia Rd., at Petroglyph Site (Wells 1277 & Hagenah in 1969, BLH); Ingham Co., along an old road in the E-central portion of woods, Sandhill Woodlot, sec. 6, T3N, R1W (Valasek 679, MSC–cited as *H. pratense* in Mich. Bot. 15:203. 1976).

3. **Hieracium aurantiacum** L. Orange Hawkweed; Devil's Paintbrush (Map 2)

Readily recognized by its several orange-red heads, prostrate stolons, and hairs more dense on the stems and leaves than usual for the next species. It has often been remarked that if the orange hawkweed were a restricted wildflower, carpeting mountain meadows, as in its native Alps, we would regard its beauty with enthusiasm; however, it is too aggressive in dry fields and waste places for most people's tastes, and can be found today even in remote Sphagnum bogs, small clearings in forests, and other sites far from the usual roadside vistas.

H. aurantiacum was apparently introduced as a garden ornamental in Vermont about 1875, and within a quarter of a century it had spread rapidly through northern New England and into Quebec (Rousseau, 1968, pp. 143-145). House (1924, p. 672) noted that it was first seen on Staten Island in 1875 and that by 1883 it had spread as far west as Buffalo. In 1895, the species was first collected in Michigan by C. F. Wheeler, at Alpena (MSC). It is strange that Wheeler did not list it in his "Additions to the Michigan Flora



Maps 1-4: Distributions of taxa of *Hieracium* subgenus *Pilosella* in Michigan, based on specimens examined.

1. *H. pilosella* (squares) and *H. flagellare* (circles).
2. *H. aurantiacum.* In addition to the counties from which one or more records are mapped, we have seen published or manuscript reports, or specimens with no more precise data, from Alcona, Alger, Berrien, and Tuscola counties and from Drummond Island (Chippewa Co.).
3. The *H. piloselloides* complex. Squares represent large-headed hairy plants which may be referred to *H. caespitosum.* In addition to the counties from which one or more records are mapped, we have seen published or manuscript reports from Berrien County and Drummond Island (Chippewa Co.). Plants are in fact of widespread occurrence throughout the state, but collectors have not yet caught up with them.
4. Apparent hybrids, *H. aurantiacum* X *H. piloselloides.*

since 1892" (Rep. St. Bd. Agr. 37:82-91. 1899); perhaps he did not consider it established. However, it was not long in spreading. C. K. Dodge wrote in December of 1912 to A. G. Ruthven (letter in Herbarium archives, MICH): "...I found a very bad weed from Alpena to St. Ignace, Hieracium aurantiacum, orange hawkweed, which as was reported there appeared about 10 years ago. I noticed it was not reported in any of our State lists that I have ever consulted.... In the mean time Prof. J. W. [sic] Beal sent me a copy of the Mich. Flora by Beal & Wheeler in which Wheeler kept his notes for many years.... In notes on Hieracium by Wheeler he has recorded orange hawkweed from Hudson Mich. in 1897 and it was then becoming a weed there. On further examination it appears that Dr. Beal did not consult these notes in compiling the last Mich. Flora.... Will say further I never saw this orange hawkweed growing before but knew it was on its way from the east."

The first published report for Michigan is apparently Dodge's for Mackinac Island, where he noted it as "Occasional in open woods like a native plant" (Rep. Mich. Acad. 15:237. 1914). The oldest collection seen from Mackinac Island is dated 1902 (E. E. Bogue, MSC).[2] Dodge later (1918) more formally reported the species as new to the state and summarized previous records. On the basis of his 1912-1914 field work along the Lake Huron shore, Dodge again reported this to be very abundant and a pernicious weed from about two miles north of Alpena to Presque Isle and Cheboygan counties, said to have appeared about 10 years previously (Mich. Geol. Biol. Surv. Publ. 31:74. 1921).

In the meantime, Gleason reported *H. aurantiacum* as "apparently new to the state" on the basis of a 1912 collection from Emmet County: "Introduced and growing along roadsides about four miles west of Levering" (Rep. Mich. Acad. 15:149. 1914). A collection by Maud Robertson (August 5, 1912, UMBS) is labeled as from a roadside 6 miles west of Levering.

Farwell (Rep. Mich. Acad. 19:261. 1918) reported the species as rare on ballast grounds at Detroit, collected in 1916, and noted that it had also been found by Billington, Chandler, and Gladewitz. McAtee, evidently ignorant of the earlier reports by Dodge, Farwell, and Gleason, again reported *H. aurantiacum* as an addition to the flora of the state (Pap. Mich. Acad. 1:165. 1923) on the basis of its discovery at Grand Rapids June 10, 1901, by Emma J. Cole, as recorded in Wheeler's annotated copy of the Beal & Wheeler 1892 "Michigan Flora." (If this was the same annotated copy seen by Dodge, it is very odd that different annotations were selected for citing by Dodge and by McAtee!) Since Miss Cole had not included this species in her *Grand Rapids Flora* published in 1901, we can safely assume that her diligent collecting accurately dates the appearance of orange hawkweed around Grand Rapids in 1901. Unfortunately there is no specimen in the Cole herbarium, recently deposited at the University of Michigan.

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[2] It may be of interest that E. E. Bogue also collected what is apparently the first specimen of this species in Ohio (Ashtabula Co. in 1895, OS, fide R. L. Stuckey, pers. comm.).

The abundance of early reports strongly suggests separate introductions of *H. aurantiacum* into Michigan, perhaps by different routes. It is certainly not possible to pinpoint an initial introduction and subsequent radiation, as it is for many introduced species. This hawkweed was at Alpena as early as 1895 and a common weed from there to the Straits by 1902; it was at Hudson (Lenawee County), in the southeastern Lower Peninsula, in 1897; it appeared in Grand Rapids, in the southwestern Lower Peninsula, in 1901. By 1917 it had been collected in Oakland, Washtenaw, Wayne, Cass, Emmet, and Cheboygan counties (also in Genesee, Midland, Chippewa, and Montcalm counties, according to Wolff, 1928). By 1919 it was collected in the far western Upper Peninsula in Gogebic County (see Darlington, Rep. Mich. Acad. 22:174. 1921). The remoteness of Isle Royale in Lake Superior posed some barrier; the first plant found there (by the Park superintendent) was at Siskiwit Camp in 1946 (G. Baggley, IRP, MSC).

Although orange hawkweed is known throughout Michigan, and the earliest records include some from the southern Lower Peninsula, it is most abundant in the northern portions of the state. It does not seem to be as aggressive in spreading southward as it is northward. Deam (Fl. Indiana, p. 1017. 1940) noted that it was first found in Indiana near the Michigan line, in 1934. Swink (Pl. Chicago Region ed. 2, pp. 222-223. 1974) noted that it is still surprisingly rare in the Chicago area, as is the next species complex also, although both are aggressive farther north in suitable climates and habitats. Both seem confined in Ohio largely to the eastern half of the state, not having been collected immediately south of Michigan prior to 1957 (Long, Prel. List Compositae Ohio [mimeo], p. 42. 1957). *H. aurantiacum* evidently arrived in Wisconsin about the same time it did in Michigan; *H. piloselloides* (sens. lat.) appeared there somewhat later and is still spreading, with both taxa more abundant northward (Johnson & Iltis, 1964).

4. **Hieracium piloselloides** Vill. King Devil; Yellow Hawkweed (Map 3)

The name *H. piloselloides* applies to the same taxon as what has long been called by the later name of *H. florentinum* All. It is also an older name than the others which have been applied to Michigan plants, all or almost all of which are included here: *H. caespitosum* Dumort. and the later *H. pratense* Tausch; *H. praealtum* Gochnat; and *H. floribundum* Wimmer & Grab. Supposed distinctions between the taxa break down in our area, as previously explained. King Devil, in the broad sense, is easily distinguished from the preceding three species by its several yellow heads, usual absence of prostrate stolons, and hairs usually sparse or absent on the stems and upper surfaces of the leaves (except sometimes toward the margins and bases and except in the few collections which could be segregated as *H. caespitosum*); the leaves are also usually more or less glaucous. The inflorescence becomes more open and diffuse than in *H. aurantiacum* as the plant matures and seed ripens.

Because of the differing characters used to distinguish species, it is not at all clear whether names applied in older literature referred to plants with the same combinations of characters as those to which the names now apply, and hence to avoid unwarranted interpretations the names originally used are retained in summarizing the history of this complex in our region. *H. florentinum* was introduced into northern New York about 1879, whence it spread rapidly northward; *H. pratense* was apparently introduced later (Hansen, 1920). House (1924, pp. 671-672) reported the former as becoming common in many sections of New York and the latter as still rare in northern New York; *H. floribundum* was likewise a rare adventive in New York. Early records were summarized by Rousseau (1963, pp. 146-149): *H. pratense* a bad weed in Quebec by 1898; *H. floribundum* rapidly spreading in Maine in 1902 and in New Brunswick by 1906; *H. florentinum* in New Brunswick and Ontario in 1905, in Quebec in 1917 (if not earlier)–coming from three sources (New York, Ontario, and New Brunswick). *H. florentinum* soon became almost or quite as common and widely distributed in eastern Canada as *H. aurantiacum*–the same history as in Michigan, where it was thoroughly established and abundant over wide areas in the late 1940's and 1950's.

H. piloselloides was first collected in Michigan by Farwell at Lake Linden, Houghton County, in 1914 (Farwell 3915, BLH); it was promptly reported (as *H. florentinum*: Rep. Mich. Acad. 17:180-181. 1917). By 1923 (Am. Midl. Nat. 8:280) Farwell could report that it "covers the sandy or gravelly hillsides near Lake Linden in great profusion" and that it "has also spread into rich muck lands of drained swamps near Calumet where it is of gigantic size, 10-15 dm. high." In 1930 (Am. Midl. Nat. 12:77-78) Farwell (taking up the name *H. piloselloides*) noted that the species was "rapidly spreading all over the Copper District," and he described plants with leaves [and peduncles] nearly glabrous as a new variety. Already pubescence variability was noted!

It seems clear that King Devil first became established in Michigan in the "Copper Country" of Houghton County, whence there are numerous specimens from the 1920's; Wolff (1928) cited it only as "established and becoming common in Houghton and Keweenaw county." Its subsequent spread is not so well documented. Collectors have almost certainly not made specimens as soon as it reached a new area. In 1939 it was collected on Bois Blanc Island in Mackinac County (Bingham, BLH). The first collection in the Lower Peninsula was from just across the Straits at Mackinaw City in 1935 (Gleason, UMBS). In 1947 it was collected in Oakland County, in the southeastern Lower Peninsula; probably by then it was in fact well distributed throughout most of the state, although other collections are all from 1948 and later. Even today collections in the herbaria of the state–as for too many weeds–under-represent its distribution. It was not collected on Isle Royale until 1958 (Voss 7924, MICH, IRP).

As suggested previously, a very few specimens with more densely hairy leaves and stems as well as large heads may possibly be segregated as *H. caespitosum* [*H. pratense*], although they are not very clearly separated from the numerous plants more comfortably included in a broad concept of *H. piloselloides.* Gates first reported this species from Michigan as found by F. Loew in Cheboygan County in 1911 (Rep. Mich. Acad. 14:103. 1913; Pap. Mich. Acad. 4:282. 1925). However, the only Cheboygan County material located was collected in 1936 (Ehlers 6066, MICH, UMBS); a similar specimen was collected along an old trail in mixed woods ca. 4.5 mi. W of Port Sanilac, Sanilac Co. in 1958 (Voss 6696, MICH); both of these collections were identified as *H. pratense* by L. H. Shinners. Three collections—all stoloniferous—from dunes between Holland and Grand Haven, Ottawa County, can be placed with these (Bazuin 6831 [det. as *H. pratense* by Fernald], 6832, & 6833 ["new this year"] in 1946, BLH). Additional collections of this large, hairy form are these: South Fox Island, Leelanau County (Test in 1962, UMBS); pasture near John R and 20 Mile Rd., Oakland County (Rogers 9301 in 1953, WUD); Sphagnum bog, Proud Lake Recreation Area, Oakland County (Hiltunen 3058 in 1961, WUD); north end of Harsen's Island, St. Clair County (Hiltunen 3117 & Hayes in 1961, WUD). Perhaps representing this extreme, although the involucres are smaller, are a collection from Oakland County near Proud Lake (Thompson S-56 in 1947, BLH) and one from Ann Arbor Tp., Washtenaw County (Dieterle in 1976, MICH, MSC).

5. **Hieracium aurantiacum × H. piloselloides**

Although 2n = 36 is the chromosome number most frequently reported (among others) for *H. aurantiacum* and the yellow-flowered complex, hybrids have rarely been seen or described in North America. House (1924, p. 672) reported an apparent hybrid between *H. aurantiacum* and *H. florentinum* in Oneida County, New York. *H. floribundum* (but not *H. florentinum*) was reported from Prince Edward Island by Erskine (1960, p. 264), and abundant intermediates with *H. aurantiacum* were said to have "ligule colour ranging from orange to yellow through externally orange, the foliage as setose as in *H. aurantiacum* but so glaucous as to approach *floribundum.*" Johnson & Iltis (1964, p. 317) reported a 1947 collection from Taylor County, Wisconsin, which they referred to *H. aurantiacum* × *H. florentinum,* saying that it closely resembled the parents [which one?] except for the ligules, which were yellow with red tips. Lepage (1971, p. 662) evidently did not know of hybrids in Quebec but suggested that ones with *H. caespitosum* should be sought there. He had earlier (1967) cited a Massachusetts specimen of *H. aurantiacum* × *H. caespitosum,* with yellow ligules red-tinted at the apex, and named the *H. aurantiacum* × *H. floribundum* hybrid found in New Brunswick as well as Prince Edward Island, describing the marginal ligules as deep red, passing to purple and yellowish. He noted the great difficulty in distinguishing herbarium specimens of hybrids involving *H. floribundum* and *H. florentinum* [*piloselloides*] because of the resemblance of these two.

There are no previous published reports of hybrids from Michigan, but such plants were to be expected. The first recognized collection of an apparent hybrid was made in 1969 (Stergios 474, MSC) in Kalamazoo County, along with the presumed parents. The situation was thoroughly discussed by Stergios (1970; see Appendix E, pp. 74-79: "Additional remarks concerning *H. aurantiacum* and the putative hybrid *H. aurantiacum* × *H. florentinum* from the Louden old-field. Summer, 1969.") He noted that the hybrid occurred only occasionally and was associated with *H. florentinum,* never in or near an aggregation of *H. aurantiacum.* Characters of both parents were expressed in leaves, stem, and inflorescence, and the plants did not appear to reproduce vegetatively. Outer ligules were orange along the margins with red bands down their centers. (Color photos show great similarity to the Delta County hybrids mentioned below.) Pollen grains of the suspected hybrid all appeared to have nuclei, indicating probable viability; about 20% of the seed appeared viable compared with about 98% of the seed of the parents. Dr. S. N. Stephenson has mentioned to us his observations in the field where Stergios worked, where honeybees visit the hawkweeds freely but show considerable flower constancy, a bee visiting either orange heads or yellow heads but very rarely both.

In 1972, Don Henson, of Manistique, discovered putative hybrids on the Garden Peninsula in Delta County and supplied specimens (Henson 384, MICH) and notes comparing them with the parents. On June 26, 1976, he took us to the site in the NW¼ sec. 26, T38N, R19W, ca. 3 miles NE of Fayette. Although it was rather late in the blooming season, we were able to find several plants which seemed obviously to be hybrids (Voss 14832 and 14833 with Böhlke & Henson, MICH, UMBS, MSC, WIS, NY). Material including the youngest buds was preserved in Newcomers solution but proved to be too old for cytological examination. However, pollen stainability with aniline blue-lactophenol was 90% or better for all hybrids as well as for the presumed parents. With this indication of high pollen viability (and noting good seed set in older heads of the hybrids), we might expect a good deal of back-crossing, as could be inferred from the description by Erskine of a full range of ligule color.

Hybrids clearly intermediate in ligule color are easily recognized in the field. If any grade closer to the parents, however, they would be less distinct–especially since there seems to be a considerable range in the normal depth of color in *H. aurantiacum.* Herbarium specimens are less easy to recognize for ligule color changes with drying. Analysis of a number of characters, such as leaf size and shape, pubescence, number of florets per head, and pappus length, showed that the hybrids *averaged* between the averages of the parents, but there was so much individual variation that single plants could not be confidently placed. In other characters, such as pollen and achene sizes, seed set, number of phyllaries per involucre, and involucre length, the hybrids and both parents were essentially the same. Stolons are regularly present in *H. aurantiacum,* absent in *H. piloselloides* at this site, and occasionally evident in the hybrid.

Sell & West (1976) merely noted in their key that most hybrids would run to *H. aurantiacum* "and can often be distinguished by their more lax or deeply furcate inflorescence." Under the treatment of this species they stated that most hybrids "can be recognized by the amount of red in the ligules." It would seem clear that hybrids can be expected to appear more or less intermediate in several morphological characters, or to recombine the characters, of the parental populations at any given site, but the most striking and reliable intermediacy is in the color of the ligules. These are an orange-yellow above, yellow toward the base of the limb; beneath (abaxial side), they are dull red-orange or brownish red except toward the margins where they are more yellow. Sometimes the red occurs only near the tip of the ligule. Bicolored ligules are not unexpected in *Hieracium* hybrids, in light of their existence in *Tragopogon,* as explained in the classic work of Ownbey (Am. Jour. Bot. 37:489. 1950), and a similar genetic mechanism could be operating.

What appears certainly to be a hybrid has also been collected in Schoolcraft County, SW¼ sec. 19, T43N, R15W (Henson 585 in 1974, MICH, BLH), with the putative parents. Casual observations by the junior author on a bicycle trip through the eastern Upper Peninsula early in the summer of 1976 suggest that hybrids are more frequent than currently recognized. Collections which may be hybrids (on the basis of apparent intermediate color or bicolored ligules) have been seen near Ryerse Lake in Mackinac County (Voss 14447 in 1974, with D. Henson, MICH, UMBS; 14827 in 1976, with M. Böhlke, MICH), but these may be only forms of *H. aurantiacum,* to which they appear very close. An apparent hybrid with bicolored ligules dried light purplish was collected in Alcona County in 1954 (Hoffman & Poltorak 614, MSC), but the specimen was not suggested as intermediate by the collectors, who merely called it *H. pratense;* it is stoloniferous and has the general aspect of *H. aurantiacum.* Plants with intermediate ligules, clearly bicolored, were found with the putative parents in Washtenaw County in 1977, in Lyndon Tp. (Wagner 77107, MICH) and in Dexter Tp. (Wagner 77110, MICH). Such plants should be watched for throughout the state.

Study of our hawkweeds by someone familiar with the European taxa might help to clarify the identity of our yellow-flowered plants. Cytological study might indicate the actual role of apomixis in our populations and clarify the presumed hybrids. Ecological and population studies might help interpret the meaning of some of the morphological characters and the influences of environmental factors on their expression. We may well have a complex of yellow-flowered taxa and hybrids between them as well as with the orange one, so that distinctions once more clear are now being lost. A Pandora's box is hereby opened for all who want to peer in.

We are especially indebted to Don Henson for bringing the hybrids to our attention and discussing his observations, to Jonathan Wendel for his aid in analysis of the hybrids as part of a course project at the University of Michigan Biological Station, and to S. N. Stephenson for making available the work of his former student Basil Stergios. This paper is based in part on a senior honors thesis presented by the junior author in April, 1976, and supported by the Honors Council of The University of Michigan. The distribution maps are based on specimens examined from the following herbaria: University of Michigan (MICH), Michigan State University (MSC), Cranbrook Institute of Science (BLH), Wayne State University (WUD), Western Michigan University (WMU), Central Michigan University (CMC), University of Michigan Biological Station (UMBS), Ohio State University (OS), Seney National Wildlife Refuge (SEN), and Isle Royale National Park (IRP).

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CURRENT STATUS OF THE GENUS HACKELIA (BORAGINACEAE) IN WISCONSIN

Johnnie L. Gentry, Jr.

Bebb Herbarium
Department of Botany-Microbiology
University of Oklahoma, Norman, 73019

Cochrane (1975) reported *Lappula floribunda* (Lehmann) Greene, known as *Hackelia floribunda* (Lehmann) I. M. Johnston by Gentry & Carr (1976), from Kewaunee County, Wisconsin. The report was based on two collections made by J. Schuette in 1892. I have recently identified both collections in the University of Wisconsin herbarium as *H. deflexa* (Wahlenberg) Opiz var. *americana* (Gray) Fernald & I. M. Johnston [*L. deflexa* (Wahlenberg) Garcke subsp. *americana* (Gray) Cochrane]. The easternmost known locality for *H. floribunda* in the United States is in Benson County, North Dakota (Peninsula of Lake Ibsen, *J. Lunell 8337,* GH, & *s.n.*, MIN, two collections), approximately 100 airline miles from the Minnesota state line. Of the 28 species of *Hackelia* known to occur in the United States, only two are present east of the Mississippi River: *H. deflexa* var. *americana* and *H. virginiana* (L.) I. M. Johnston (Gentry & Carr, 1976).

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REVIEWS

THE FLORA OF MANITOULIN ISLAND and the adjacent islands of Lake Huron, Georgian Bay and the North Channel. By J. K. Morton. Biology Series No. 15. Department of Biology, University of Waterloo, Waterloo, Ontario. 1977. 62 pp. + map. $4.50 (postpaid).

After introductory material on geology, glacial history, and composition and origin of the flora, this consists of an annotated list of 906 species, often with informative notes on special problems of taxonomy or identification. This is a valuable account for anyone interested in the flora of the Great Lakes region, with many interesting records of both native and introduced species. The composition is typographically attractive, but there is an unfortunately high incidence of errata (e.g., *Cakile "edentulata," Asparagus "officinale," Phryma "lanceolata"*).

THE LIFE OF ISLE ROYALE. By Napier Shelton. National Park Service, Washington. 1975. 144 pp. $3.30, paperbound (Government Printing Office).

Illustrated with numerous photographs in color, this attractive volume summarizes the geological history, human occupation, and natural communities of Isle Royale. Plants pictured–even the fine *Arabis lyrata* on the cover–are often not identified, even though birds and mammals almost always are. An appendix lists fishes, amphibians and reptiles, birds, mammals, and trees of the Park, but only those other plants mentioned in the text. Persons who have been to Isle Royale and those who plan a trip will appreciate this ecological handbook.

–E. G. Voss

THE DIATOMS OF DOUGLAS LAKE–A PRELIMINARY LIST

N. A. Andresen
Department of Biology
Eastern Michigan University
Ypsilanti, 48197

E. F. Stoermer
Great Lakes Research Division
University of Michigan
Ann Arbor, 48109

When an ecosystem such as Douglas Lake is intensively studied over a period of time, lists of the local flora and fauna are usually generated as one facet of the investigations. Such is the case with our recent studies (Stoermer, 1977; Andresen, 1974, 1976). We consider it appropriate to present this list as a summary of taxa encountered to date so that others working on this lake may benefit by having some reference to the extent of the diatom flora. With Stoermer's work on post-Pleistocene assemblages and Andresen's work on recent sedimentary assemblages, we believe we have encountered a substantial fraction of taxa which have existed in the lake. Previous works on Douglas Lake which contain references to diatoms have been consulted (Chandler, 1937; Neel, 1948; Stoermer & Yang, 1971; Tucker, 1957; Young 1945), and the taxa listed have been checked against our composite list. In some cases we were unable to verify a previous record among our collections; we have indicated these with an asterisk preceding the name. Synonyms given for *Epithemia* and *Gomphonema* in Partick & Reimer (1975) are listed for reference.

Achnanthes affinis Grun. in Cl. & Grun.
A. biasolettiana (Kütz.) Grun. in Cl. & Grun.
A. bioreti Germain
A. calcar Cl.
A. clevei Grun. in Cl. & Grun. var. clevei
A. clevei var. rostrata Hust.
A. conspicua A. Mayer
A. deflexa Reim. in Patr. & Reim.
A. detha Hohn & Hellerm.
A. exigua Grun. in Cl. & Grun. var. exigua
A. exigua var. constricta (Grun.) Hust. in Schroeder
A. exigua var. heterovalva Krasske
A. flexella (Kütz.) Brun var. flexella
A. flexella var. alpestris Brun
A. hauckiana Grun. in Cl. & Grun.
A. lanceolata (Bréb.) Grun. in Cl. & Grun. var. lanceolata
A. lanceolata var. dubia Grun. in Cl. & Grun.
A. lanceolata var. omissa Reim. in Patr. & Reim.
A. lapponica (Hust.) Hust. var. lapponica
A. lapponica var. ninckei (Guerm. & Mang.) Reim. in Patr. & Reim.
A. laterostrata Hust.
A. lauenburgiana Hust.
A. levanderi Hust.
A. linearis (Wm. Sm.) Grun. in Cl. & Grun. fo. linearis
A. linearis fo. curta H. L. Sm. in Boyer
A. microcephala (Kütz.) Grun. in Cl. & Grun.
A. minutissima Kütz. var. minutissima
A. minutissima var. cryptocephala Grun.
A. minutissima var. robusta Hust.
A. nollii Bock
A. oestrupi (A. Cl.) Hust.
A. peragalli Brun & Hérib. var. peragalli
A. peragalli var. fossilis Temp. & Perag.
A. pinnata Hust.

A. suchlandti Hust.
A. trinodis (Wm. Sm.) Grun.

Amphipleura pellucida (Kütz.) Kütz.

Amphiprora ornata J. W. Bail. = Entomoneis ornata (J. W. Bail.) Reim. in Patr. & Reim.

Amphora cruciferoides Stoerm. & Yang
A. michiganensis Stoerm. & Yang
A. ovalis (Kütz.) Kütz. var. ovalis
A. ovalis var. libyca (Ehr.) Cl.
A. ovalis var. pediculus (Kütz.) V. H. ex DeT.
A. parallelistriata Mang.
A. perpusilla (Grun.) Grun. in V. H.
A. sibirica Skv. & Meyer
A. subcostulata Stoerm. & Yang
A. veneta Kütz. var. veneta
A. veneta var. capitata Haworth

Anomoeoneis styriaca (Grun.) Hust.
A. vitrea (Grun.) Ross ex Reim. in Patr. & Reim.

Asterionella formosa Hass.

Caloneis alpestris (Grun.) Cl.
C. bacillaris var. thermalis (Grun.) A. Cl.
C. bacillum (Grun.) Cl.
C. hebes (Ralfs) Patr.
C. hyalina Hust.
C. lewisii Patr.
C. limosa (Kütz.) Patr. in Patr. & Reim.
C. schumanniana (Grun.) Cl.
C. silicula var. truncatula (Grun.) Cl.
C. ventricosa var. truncatula (Grun.) Meist.

Campylodiscus noricus var. hibernicus (Ehr.) Grun.

Cocconeis diminuta Pant.
C. disculus (Schum.) Cl. in Cl. & Jentzsch
C. pediculus Ehr.
C. placentula Ehr. var. placentula
C. placentula var. euglypta (Ehr.) Cl.
C. placentula var. lineata (Ehr.) V. H.

Coscinodiscus decrescens Grun.

Cyclotella atomus Hust.
*C. bodanica Eulenst.
C. comta (Ehr.) Kütz. var. comta
*C. comta var. radiosa Grun. in V. H.
C. glomerata Bachm.
C. kuetzingiana Thw. var. kuetzingiana
C. kuetzingiana var. radiosa Fricke
C. meneghiniana var. plana Fricke
C. michiganiana Skv.
C. ocellata Pant.
C. operculata (Ag.) Kütz.
C. stelligera (Cl. & Grun.) V. H.
C. pseudostelligera Hust.

Cymatopleura cochlea Brun
*C. elliptica (Bréb. & Godey) W. Sm.
C. solea (Bréb. & Godey) W. Sm.

Cymbella aequalis W. Sm.
C. affinis Kütz.
*C. amphicephala Näg. var. amphicephala
C. amphicephala var. subundulata Cl.
*C. angustata (W. Sm.) Cl.
C. aspera (Ehr.) Hérib.
*C. austrica Grun.
C. cesatii (Rabh.) Grun. ex A. S.
C. cistula (Ehr.) Kirch. in Cohn var. cistula
C. cistula var. maculata (Kütz.) V. H.
C. cuspidata Kütz.
C. cymbiformis Ag.
C. delicatula Kütz.
C. diluviana (Krass.) Florin (syn. Navicula diluviana Krasske)
C. ehrenbergii Kütz. = C. inaequalis (Ehr.) Rabh.
C. hauckii V. H. in Hauck & Richter
C. hebridica Grun. ex Cl.
C. hustedtii Krasske
C. hybrida Grun. ex Cl.
C. inaequalis (Ehr.) Rabh. (syn. C. ehrenbergii Kütz.)
C. laevis Näg. ex Kütz.
C. lanceolata (Ehr.) Kirch. in Cohn
C. latens Krass. = C. minuta var. latens (Krasske) Reim. in Patr. & Reim.
C. leptoceros (Ehr.) Rabh. var. leptoceros
C. leptoceros var. rostrata Hust.
C. microcephala Grun. in V. H.
C. minuta Hilse ex Rabh. var. minuta
C. minuta var. latens (Krasske) Reim. in Patr. & Reim. (syn. C. latens Krasske)
C. minuta var. silesiaca (Bleisch ex Rabh.) Reim in Patr. & Reim.
C. muelleri Hust.
C. naviculiformis Auersw. ex Heib.
C. norvegica Grun.
C. obtusa Greg.
C. obtusiuscula Kütz.
C. parva (W. Sm.) Cl.
C. parvula Krasske
C. prostrata (Berk.) Cl.
C. proxima Reim. in Patr. & Reim.
C. pusilla Grun.
*C. rupicola Grun.
C. sinuata Greg. var. sinuata
C. sinuata var. antiqua (Grun.) Cl.
C. subaequalis Grun. in V. H.
*C. tumida (Bréb.) V. H.
C. triangula (Ehr.) Cl.

C. turgida Greg.
C. ventricosa Ag. = C. minuta Hilse ex Rabh. var. minuta

Cystopleura spp. - Epithemia spp.

Denticula tenuis var. crassula (Näg. ex Kütz.) West & West

Diatoma tenue var. elongatum Lyngb.
*D. vulgare var. ovale (Fricke) Hust.

Diploneis boldtiana Cl.
D. elliptica (Kütz.) Cl.
D. finnica (Ehr.) Cl.
D. oblongella (Näg.) Ross
D. oculata (Bréb.) Cl.
D. ovalis (Hilse) Cl.
D. parma Cl.
*D. puella (Schum.) Cl.

Entomoneis ornata (J. W. Bail.) Reim. in Patr. & Reim. (syn. Amphiprora ornata J. W. Bail.)

Epithemia adnata (Kütz.) Bréb. var. adnata (syn. E. zebra (Ehr.) Kütz. var. zebra)
E. adnata var. porcellus (Kütz.) Patr. in Patr. & Reim. (syn. E. zebra var. porcellus (Kütz.) Grun.)
E. adnata var. saxonica (Kütz.) Patr. in Patr. & Reim. (syn. E. zebra var. saxonica (Kütz.) Grun.)
E. argus (Ehr.) Kütz. var. argus
E. argus var. alpestris (W. Sm.) Grun.
E. reichelti Fricke
E. smithii Carruthers in Gray
*E. sorex Kütz.
E. turgida (Ehr.) Kütz. var. turgida
*E. turgida var. granulata (Ehr.) Brun
E. zebra (Ehr.) Kütz. var. zebra = E. adnata (Kütz.) Bréb. var. adnata
E. zebra var. porcellus (Kütz.) Grun. = E. adnata var. porcellus (Kütz.) Patr. in Patr. & Reim.
*E. zebra var. saxonica (Kütz.) Grun. = E. adnata var. saxonica (Kütz.) Patr. in Patr. & Reim.

Eucocconeis spp. = Achnanthes spp.

*Eunotia arcus Ehr.
E. curvata (Kütz.) Lagerst.
*E. formica Ehr.
E. praerupta Ehr.

Fragilaria brevistriata Grun. in V. H. var. brevistriata
F. brevistriata var. inflata (Pant.) Hust.
F. capucina Desm. var. capucina
F. capunica var. mesolepta Rabh.
F. construens (Ehr.) Grun. var. construens
F. construens var. binodis (Ehr.) Grun.
F. construens var. minuta Temp. & Perag.
F. construens var. subsalina Hust. in Thienemann
F. construens var. venter (Ehr.) Grun.
F. crotonensis Kitton
F. heideni Østr.
F. intermedia Grun. var. intermedia
F. intermedia var. fallax (Grun.) A. Cl.
F. lapponica Grun. in V. H.
F. leptostauron (Ehr.) Hust. var. leptostauron
F. leptostauron var. dubia (Grun.) Hust.
F. leptostauron var. fossilis (Grun.) Řeháková
F. leptostauron var. rhomboides (Grun.) Hust.
F. pinnata Ehr. var. pinnata
F. pinnata var. lancettula (Schum.) Hust.
F. vaucheriae (Kütz.) Boye Peters. var. vaucheriae
F. vaucheriae var. capitellata (Grun.) Patr. in Patr. & Reim. (syn. Synedra vaucheriae var. capitellata (Grun.) Cl.)

*Gomphocymbella ancyli (Cl.) Hust.

Gomphonema abbreviatum fo. inflatum Hust.
G. acuminatum Ehr. var. acuminatum
G. acuminatum var. coronatum (Ehr.) Rabh. = G. acuminatum Ehr. fide Patr. in Patr. & Reim.
G. acuminatum var. pusillum Grun.
G. angustatum (Kütz.) Rabh. var. angustatum
G. angustatum var. productum Grun. in V. H.
G. clevei Fricke
G. constrictum Ehr. var. constrictum = G. truncatum Ehr. fide Patr. in Patr. & Reim.
G. constrictum var. capitatum (Ehr.) V. H. = G. truncatum var. capitatum (Ehr.) Patr. in Patr. & Reim.
G. dichotomum Kütz. (syn. G. intricatum var. pumilum Grun. in V. H.)
G. gracile Ehr. var. gracile
*G. gracile var. auritum Kütz. = G. gracile Ehr. var. gracile fide Patr. in Patr. & Reim.
G. grovei M. Schmidt
G. intricatum Kütz. var. intricatum
G. intricatum var. pumilum Grun. in V. H. = G. dichotoma Kütz. fide Patr. in Patr. & Reim.
G. longiceps Ehr. = G. mustela Ehr. fide Patr. in Patr. & Reim.

*G. mustela Ehr. (syn. G. longiceps Ehr. fide Patr. in Patr. & Reim.)
G. olivaceoides Hust.
G. olivaceum (Lyngb.) Kütz.
G. subclavatum (Grun.) Grun.
G. subtile Ehr. var. subtile
G. subtile var. sagitta (Schum.) Grun. in V. H.
G. truncatum Ehr. (syn. G. constrictum Ehr. var. constrictum fide Patr. in Patr. & Reim.)
G. truncatum var. capitatum (Ehr.) Patr. in Patr. & Reim. (syn. G. constrictum var. capitatum (Ehr.) V. H.)

Gyrosigma acuminatum (Kütz.) Rabh.
G. attenuatum (Kütz.) Rabh.
G. sciotense (Sulliv. & Wormley) Cl.

Hantzschia amphioxys (Ehr.) Grun. in Cl. & Grun.

Mastigloia grevillei Wm. Sm.
*M. elliptica var. dansei (Thw.) Cl.
*M. smithii Thw. var. smithii
M. smithii var. amphicephala Grun. in V. H.
M. smithii var. lacustris Grun. in Schneid.

*Melosira ambigua (Grun.) O. Müll.
M. arenaria Moore
*M. crenulata (Ehr.) Kütz.
M. distans (Ehr.) Kütz.
M. granulata (Ehr.) Ralfs in Pritch. var. granulata
M. granulata var. angustissima O. Müll.
M. islandica O. Müll.
*M. varians Ag.

Meridion circulare (Grev.) Ag. var. circulare
M. circulare var. constrictum (Ralfs) V. H.

Navicula abiskoensis Hust.
N. acceptata Hust.
N. americana Ehr. var. americana
N. americana var. bacillaris Perag. & Hérib. in Hérib.
N. amphibola var. polymorpha Fusey
N. anglica var. subsalsa (Grun.) Cl.
N. aurora Sov.
N. bacillum Ehr.
N. bryophila Boye Peters.
N. capitata var. hungarica (Grun.) Ross
N. clamans Hust.
N. clementis var. quadristigmata Mang.
N. cocconeiformis Greg. ex Grev.
N. costulata Grun. in Cl. & Grun.
N. cryptocephala Kütz. var. cryptocephala
N. cryptocephala var. veneta (Kütz.) Rabh.
N. cuspidata (Kütz.) Kütz.
N. decussis Østr.
N. dicephala Ehr.
N. diluviana Krasske = Cymbella diluviana (Krasske) Florin
N. elginensis (Greg.) Ralfs var. elginensis
N. elginensis var. rostrata (A. Mayer) Patr. in Patr. & Reim.
N. exigua (Greg.) Grun. var. exigua
N. exigua var. capitata Patr.
N. explanata Hust.
N. gastrum (Ehr.) Kütz.
N. gibbosa Hust.
N. globosa Meist.
N. gottlandica Grun. in V. H.
N. graciloides A. Mayer sensu Hustedt
N. hasta Pant.
N. imbricata Bock
N. jaagii Meist.
N. jaernefeldtii Hust.
N. lacustris Greg.
N. lanceolata (Ag.) Kütz. var. lanceolata
N. lanceolata var. cymbula (Donk.) Cl.
N. latens Krasske
N. laterostrata Hust.
N. levanderi Hust.
N. menisculus Schum. var. menisculus
N. menisculus var. upsaliensis Grun. in V. H.
N. minima Grun. in V. H. var. minima
N. minima var. okamurae Skv.
N. minuscula Grun.
N. minusculoides Hust.
N. monoculata Hust.
N. mutica Kütz. var. mutica
N. mutica var. cohnii (Hilse) Grun. in V. H.
N. oblonga (Kütz.) Kütz.
N. paludosa (Hust.) Hust.
N. pelliculosa (Bréb. ex Kütz.) Hilse
*N. "pelucida" Kütz. (nom. nud.)
*N. peregrina (Ehr.) Kütz.
N. placentula (Ehr.) Kütz.
N. platycephala O. Müll.
N. pseudoscutiformis Hust.
N. pseudoventralis Hust.
N. pupula Kütz. var. pupula f. pupula
N. pupula var. capitata Skv. & Meyer
N. pupula f. rectangularis (Greg.) Grun. in Cl. & Grun.
*N. pusilla W. Sm.
N. pygmaea Kütz.
N. radiosa Kütz. var. radiosa
N. radiosa var. parva Wall.
N. radiosa var. tenella (Bréb.) Grun. in V. H.

N. reinhardtii (Grun.) Grun. in Cl. & Grun.
N. rhynchocephala Kütz. var. rhynchocephala
N. rhynchocephala var. amphiceros (Kütz.) Grun.
N. rotunda Hust.
N. scutelloides W. Sm. ex Greg.
N. seminoides Hust.
N. seminuloides Hust.
N. seminulum Grun.
N. stroesei (Østr.) A. Cl.
N. subhamulata Grun. in V. H.
N. subocculata Hust.
N. subrotundata Hust.
N. tantula Hust.
N. tridentula Krasske
N. tripunctata var. schizonemoides (V. H.) Patr.
N. tuscula Ehr. fo. tuscula
N. tuscula fo. minor Hust.
N. tuscula fo. obtusa Hust.
N. tuscula fo. rostrata Hust.
N. ventralis Krasske
N. verecunda Hust.
N. viridula (Kütz.) Kütz. var. viridula
N. viridula var. linearis Hust.
N. vulpina Kütz.
N. wittrockii (Lagerst.) Temp. & Perag.

Neidium affine (Ehr.) Pfitz. var. affine
N. affine var. ceylonicum (Skv.) Reim.
N. affine var. hankense (Skv.) Reim.
N. binode (Ehr.) Hust.
N. bisulcatum var. baicalense (Skv. & Meyer) Reim.
*N. dilatatum (Ehr.) Patr.
N. dubium (Ehr.) Cl. fo. dubium
N. dubium fo. constrictum Hust.
N. hitchcockii (Ehr.) Cl.
N. iridis (Ehr.) Cl. var. iridis
N. iridis var. vernale Reich.
N. temperei Reim.

Nitzschia acicularioides Archib.
N. amphibia Grun.
N. angustata (W. Sm.) Grun. in Cl. & Grun. var. angustata
N. angustata var. acuta Grun.
N. baccata Hust.
N. confinis Hust.
N. denticula Grun. in Cl. & Grun.
N. dissipata (Kütz.) Grun.
N. fonticola Grun. in V. H. var. fonticola
N. fonticola var. pelagica Hust.
N. frustulum var. perminuta Grun.
N. holsatica Hust.
N. kuetzingiana Hilse
N. linearis W. Sm.
N. macilenta Greg.
N. mediocris Hust.
N. palea (Kütz.) W. Sm.
N. recta Hantz. ex Rabh.
N. sigmoidea (Ehr.) W. Sm.
N. sinuata var. tabellaria (Grun.) Grun. in V. H.
N. spiculoides Hust.
N. sublinearis Hust.
N. subtilis (Kütz) Grun. in Cl. & Grun.
N. tropica Hust.

Oestrupia zachariasi (Reich.) Hust.

Opephora ansata Hohn & Hellerm.
O. martyi Hérib.

Pinnularia abaujensis var. linearis (Hust.) Patr.
P. biceps Greg.
P. borealis var. rectangularis Carlson
P. brebissonii (Kütz.) Rabh.
*P. divergens var. elliptica (Grun.) Cl.
P. legumen (Ehr.) Ehr.
P. major (Kütz.) Rabh.
P. microstauron (Ehr.) Cl.
P. tenuis Greg.
P. undulata Greg.
P. viridis (Nitz.) Ehr. var. varidis
P. viridis var. commutata (Grun.) Cl.

Plagiotropis lepidoptera var. proboscidea (Cl.) Reim. in Patr. & Reim. (syn. Tropidoneis lepidoptera var. probiscidea Cl.)

Rhizosolenia eriensis H. L. Sm.

Rhopalodia gibba (Ehr.) O. Müll. var. gibba
R. gibba var. ventricosa (Ehr.) Grun.

Stauroneis acuta W. Sm.
S. acutiuscula Perag. & Hérib. in Hérib.
S. anceps Ehr.
S. dilatata Ehr.
S. fluminea Patr. & Freese
*S. obtusa Lagerst.
*S. parvula Jantsch.
S. phoenicenteron (Nitz.) Ehr.
S. smithii Grun. var. smithii
S. smithii var. minima Haworth

Stephanodiscus alpinus Hust. ex Huber-Pest.
S. asteraeus (Ehr.) Grun. ex Cl. & Grun.
S. minutus Grun. ex Cl. & Möll.
S. niagarae Ehr. var. niagarae
S. niagarae var. magnificus Fricke
S. tenuis Hust.
S. transilvanicus Pant.

Surirella angusta Kütz.

S. biseriata Bréb. & Godey
*S. elegans Ehr.
S. guatemalensis Ehr.
S. linearis W. Sm. var. linearis
S. linearis var. constricta (Ehr.) Grun.
S. linearis var. helvetica (Brun) Meist.
S. robusta Ehr.

Synedra acus Kützt.
*S. amphicephala Kützt.
S. capitata Ehr.
S. cyclopum Brutschy
S. delicatissima W. Sm. var. delicatissima
S. delicatissima var. angustissima Grun. ex V. H.
S. demerarae Grun. in V. H.
S. filiformis Grun. var. filiformis
S. filiformis var. exilis A. Cl.
S. parasitica (W. Sm.) Hust.
*S. puchella var. longissima (W. Sm.) Schonf. = S. ulna var. biceps (Kützt.) Schonf.
S. rumpens var. fragilarioides Grun. in V. H.
S. tenera W. Sm.
S. ulna (Nitz.) Ehr. var. ulna
S. ulna var. biceps (Kützt.) Schonf. (syn. S. ulna var. longissima (W. Sm.) Brun.)
S. ulna var. chaseana Thomas in Walker & Chase
S. ulna var. danica (Kützt.) V. H.
S. ulna var. longissima (W. Sm.) Brun
S. vaucheriae var. capitellata (Grun.) Cl. = Fragilaria vaucheriae var. capitellata (Grun.) Patr. in Patr. & Reim.

Tabellaria fenestrata (Lyngb.) Kützt.
T. flocculosa (Roth (Kützt.

Tropidoneis lepidoptera var. proboscidea Cl. = Plagiotropis lepidoptera var. proboscidea (Cl.) Reim. in Patr. & Reim.

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THE DIATOM FLORA OF TIPLADY BOG, MICHIGAN

Kyle D. Hoagland
School of Life Sciences
University of Nebraska, Lincoln, 68588

Forrest M. Begres
Department of Biology
Eastern Michigan University
Ypsilanti, Michigan 48197

The higher plant communities of a number of Michigan bogs (and fens) have been described (Coburn et al., 1932; Dean & Coburn, 1927; Dutro & Cohoe, 1938; Gates, 1942; Goe et al., 1924; Heinselman, 1965; Jewell & Brown, 1929; Sigler & Woollett, 1926; Welch, 1936, 1938a, 1938b; Woollett et al., 1925). However, we have knowledge of only one descriptive study of the extant diatom (Bacillariophyceae) communities of a Michigan bog (Dodd, 1973). Similarly, relatively few studies have been completed on extant microfloras of bogs in other midwestern states. Reimer (1961) reported on the diatoms of Cabin Creek raised bog in Indiana. The diatoms of Excelsior Fens in northwestern Iowa were investigated by Shobe, Stoermer & Dodd (1963), and the algal flora of the Urbana raised bog in Ohio was studied by Chapman (1934). The diatoms of two other bogs in the United States (Texas & Connecticut) were described by Patrick (1946, 1954).

The diatom communities of Tiplady Bog, a relatively large, alkaline "bog" (actually a rich fen) in southeastern Michigan, were investigated at different seasons in 1974 and 1975. The study sought to characterize the diatom components of the planktonic, epiphytic and epipelic communities as well as the physiochemical properties of the open water at the time of sampling. Tiplady Bog is located at the junction of Tiplady and Silver Hill Roads in Livingston County (T1N., R4E, S33) near Hell (Fig. 1) in a lowland region of poor drainage and a high water table. The water sources for the bog include several small, spring-fed streams and seepage from adjacent wetland. The open water area (site 1) is relatively small (see Table 1) and nearly free of emergent and floating aquatic plants. An abundant amount of *Chara* is present in shallow water adjacent to the mat edge. The bottom sediments exhibit a build-up of decomposed organic matter, dark-brown in color. The open water is surrounded on the south, west and northwest by a Sphagnum mat and on the east and northeast by a wetland region consisting of standing aquatics, mainly *Typha* and various members of the Cyperaceae. The soil of the entire bog area consists of Carlisle Muck, a finely divided and dark-colored organic soil consisting of well-decomposed organic matter (USDA 1974).

Samples were collected on four occasions in 1974 and 1975 (11 April 1974, 13 August 1974, 15 November 1974, and 24 March 1975). Quantitative plankton samples were collected at site 1 (the open-water site) by filtering a one-liter surface sample

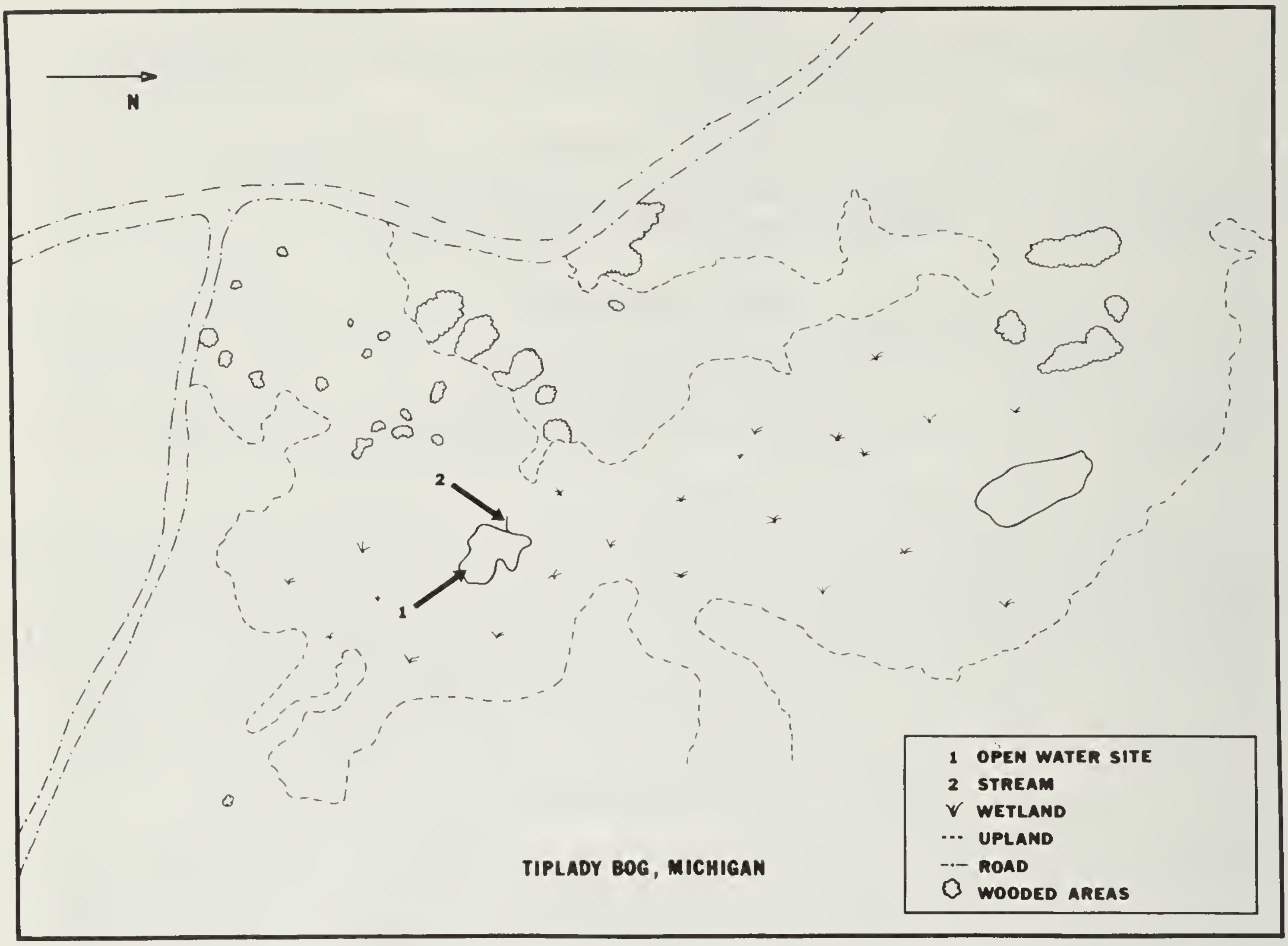

Fig. 1. Tiplady Bog and surrounding area (scale 1:1,500).

TABLE 1. Morphometric properties of Tiplady Bog (open water).

Length (m)	46
Width (m)	33
Maximum Depth (m)	3.3
Approx. Area (m^2)	1385
Approx. Volume (m^3)	1521
Approx. Mean Depth (m)	1.1

through a 25-mesh plankton net. Epipelic samples were taken from the deepest portion of open water (site 1, 3.3 m) by gently disturbing the sediment-water interface with a Van Dorn bottle before closing the instrument. Epiphytic samples were obtained by scraping the stems of *Nymphaea* and *Nuphar* and by squeezing *Sphagnum* from the mat edge and *Chara* from shallow water adjacent to the mat.

Water samples for physicochemical analysis were collected simultaneously with biological samples. Samples were obtained from the surface and from depths of 1.0, 2.0, 3.0, and 3.3 meters at site 1 (open water). The pH, conductivity and dissolved oxygen were measured instrumentally in the field (using Beckman, Scientific Instruments, and Yellow Springs Instruments, respectively). The remaining parameters were measured in the laboratory within 1½ hours of collection using a Hach Portable Engineer's Laboratory Kit.

The plankton and periphyton materials were "cleaned" of organic matter with 27.5% hydrogen peroxide and potassium dichromate (van der Werff, 1955). A small portion of the cleaned material was air dried onto a coverslip which was later inverted and permanently mounted in Hyrax. Slides were examined at 1187.5X with a Leitz microscope using a fluorite objective (N.A. 1.32). About 300 valves were identified from each epiphytic and epipelic sample, and 1000 valves were examined from each quantitative plankton sample.

The results of the physiochemical analyses are presented in Table 2. These data partially characterize the physicochemistry of the Tiplady Bog. No attempt has been made to determine which if any of these parameters strongly influences the structure of the diatom communities.

In all, approximately 7,000 valves were identified and tabulated, revealing a total of 163 taxa representing 35 genera (Table 3).

Of the three communities examined, the plankton community was represented by the greatest number of taxa (103). However, this is very likely a result of the fact that many of the specimens observed in the plankton originated from other habitats, as the plankton community of Tiplady Bog was never well developed (max. of 7.15×10^3 cells/1). Taxa which seem to prefer a planktonic existence and dominated or were abundant in the plankton community include *Cyclotella comta, C. kützingiana, Melosira granulata* and *Achnanthes minutissima.* It should be noted that *A. minutissima* was also well represented in the epiphytic communities, and it is difficult to

TABLE 2. Physicochemical data from Site 1 (open water), 1974-1975.

		Depth			
Parameter		Surf.	1m	2m	3m
pH	M*	7.77	7.75	7.70	7.68
	R	7.47-7.90	7.21-8.06	7.14-8.05	7.18-8.00
**Conductivity (micromhos)		404			
Dissolved Oxygen (mg/l)	M	10.5	10.7	10.3	9.1
	R	8.3-14.7	7.6-14.3	6.7-14.3	2.0-14.2
Ortho-phosphate (mg/l)	M	0.08	0.09	0.07	0.07
	R	0.03-0.15	0.03-0.19	0.02-0.10	0.03-0.15
Total Alkalinity (as mg/l $CaCO_3$)	M	193	192	200	197
	R	160-220	150-220	165-260	170-220
**Hardness (as mg/l $CaCO_3$)		200			
Nitrate-N (mg/l)	M	0.24	0.19	0.23	0.26
	R	0.05-0.40	0.35-0.40	0.06-0.40	0.04-0.60
**Ammonium-N (mg/l)		0.6			
Silica (mg/l)	M	13	12	13	13
	R	5-16	6-16	7-17	5-17
Sulfate (mg/l)	M	22	21	21	23
	R	17-28	12-29	13-32	13-34

*M = mean, R = range

**One sampling date only, mean of values from 1, 2 and 3 meter samples.

TABLE 3. Planktonic, epiphytic, and epipelic diatoms from Tiplady bog indicating relative abundance in each sample; R = rare (occurring 1 to 5 times in a 300 valve count or 1000 valve count of plankton); U = uncommon (occurring 6 to 20 times in a 300 valve count or 1000 valve count of plankton); C = common (occurring 21 to 50 times in a 300 valve count or 21 to 100 times in a 1000 valve count of plankton); A = abundant (occurring 51 to 100 times in a 300 valve count or 101 to 500 times in a 1000 valve count of plankton); D = dominant (occurring more than 100 times in a 300 valve count or more than 500 times in a 1000 valve count of plankton). *New to Michigan.

	Planktonic				Epiphytic						Epipelic			
	11 Apr.	13 Aug.	15 Nov.	24 Mar.	Nuphar (24 Mar.)	Chara (24 Mar.)	Nymphaea (11 Apr.)	Mat (11 Apr.)	Mat (13 Aug.)	Mat (24 Mar.)	11 Apr.	13 Aug.	15 Nov.	24 Mar.
Achnanthes clevei Grun.		R												R
exigua var. heterovalva Krasske			R							R	R	R	R	R
flexella (Kütz.) Brun	U	R	U	R		U	R	U	R	R		R	R	R
lanceolata (Bréb.) Grun.								R	C	R	R	R	R	U
var. capitata O. Müll.														R
var. dubia Grun.												U		
var. elliptica Cl.													R	
minutissima Kütz.	A	A	A	A	D	D	A	A	A	A	C	U	C	A
Amphipleura pellucida Kütz.	U	R	U	R	R						R			
Amphiprora ornata J. W. Bail.			R											
Amphora ovalis var. libyca (Ehr.) P. T. Cl.	U	R	C	R		U		R		R	U	C	U	R
var. pediculus (Kütz.) V. H. ex DeT.						R							R	R
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.								R						
vitrea (Grun.) Ross	U	R	R	R	R	R		R	R	R	R			U
Asterionella formosa Hass.	U		R	C										
Caloneis bacillaris var. thermalis (Grun.) A. Cl.								R						
bacillum (Grun.) P. T. Cl.	R								U	R				
Cocconeis placentula var. euglypta (Ehr.) P. T. Cl.		R		R										
Coscinodiscus* rothii var. subsalsa (Juhl.-Dannf.) Hust.		R												
Cyclotella comta (Ehr.) Kütz.	C	A	C	C						R			R	U
kützingiana Thw.	C	C	A	C	U	R	R	U	U	U	C	C	C	U
meneghiniana Kütz.	U	C		R					R	R				
Sp. #1 (see Fig. 3B)	R	C												
stelligera P. T. Cl. & Grun.		U	R											
Cymatopleura elliptica (Bréb.) Wm. Sm.													R	

solea (Bréb.) Wm. Sm.	R		R									R	R	
*var. gracilis Grun.			R											
Cymbella affinis Kütz.	R		R		R			R			R			R
amphicephala Naeg.	R		U			R		R		R		R		
aspera (Ehr.) Heribaud			R											
caespitosa (Kütz.) Brun.								R	R					
cesatii (Rabh.) Grun.	R	U	U	R	R	R		U		R		R	R	R
cf. cesatii (Rabh.) Grun.	R				R					R				
cistula (Ehr.) Kirch	U	U	U	R	R	R		R				R	R	
cuspidata Kütz					R	R								
delicatula Kütz.	R		U	U	R	R	U	C	R	R	R	R	R	R
inaequalis (Ehr.) Rabh.			U					R					R	
laevis Naeg.		R				R		R		R				
microcephala Grun.	U	R	U	U	R	U	R	C	U	R	U	R	U	R
naviculiformis Auersw.		R									R	R		
norvegica Grun.	R				R									
rupicola Grun.						R		R						
*ruttneri Hust.							U			R				
*schweickerdtii Chol.				R										
*turgida var. pseudogracilis Chol.				R										
ventricosa Kütz.			U			R								
Denticula elegans Kütz.					U									
Diatoma tenue var. elongatum Lyngb.				U										
vulgare Bory				C		R								
Diploneis oblongella (Naeg. ex Kütz.) Ross	R		R	R	R				R	R	R			
Eunotia arcus Ehr.	C	C	C	U	U	U	C	U	R	U	U	U	U	U
curvata (Kütz.) Lager.							R		R	R				
flexuosa Bréb. ex Kütz.	U	R	U		R							R		
Fragilaria brevistriata Grun.	A			C				U	U	C			U	U
*var. inflata (Pant.) Hust.		U												
*var. subcapitata Grun.			R											
construens (Ehr.) Grun.	C	C	C			R	R				U	A	C	C
*var. venter f. lata Mayer					R		R							
crotonensis Kitton	C	R	U											
leptostauron (Ehr.) Hust.	R			C	U	U	U	U	U	C	C	U	C	C
*pinnata var. intercedens (Grun.) Hust.								R						
*vaucheriae (Kütz.) Peters.								R						
virescens Ralfs													R	
Frustulia vulgaris (Thw.) DeT.						R								
Gomphonema acuminatum Ehr.		U										R		
var. coronata (Ehr.) Wm. Sm.	R		R		R		R			R				
*angustatum (Kütz.) Rabh.									R					
*gracile Ehr.						R		U					R	R
var. auritum (A. Braun) Grun.						U							R	
*var. lanceolatum (Kütz.) P. T. Cl.								R						
*var. naviculoides (Wm. Sm.) Grun.			R											
insigne var. elongatum Mayer		R										R		

TABLE 3. Continued

	Planktonic				Epiphytic						Epipelic			
	11 Apr.	13 Aug.	15 Nov.	24 Mar.	Nuphar (24 Mar.)	Chara (24 Mar.)	Nymphaea (11 Apr.)	Mat (11 Apr.)	Mat (13 Aug.)	Mat (24 Mar.)	11 Apr.	13 Aug.	15 Nov.	24 Mar.
intricatum Kütz.	R	U	A	U							U	U	U	U
*f. pusillum Mayer									U					
var. pumilum Grun.	C			C	U	U	D	R	U	C	A	U	U	U
olivaceum (Lyngb.) Kütz.				U		R								
*parvulum (Kütz.) Grun.						R								
*var. exilissima Grun.	R													
*var. micropus (Kütz.) P. T. Cl.	U									U	R			
subtile Ehr.											R			
*f. angusta V. H.					R									
Gyrosigma spencerii (Que.) Grif. & Hen.												R		
Hantzschia amphioxys var. vivax (Hantz.) Grun.													R	
Mastogloia grevillei Wm. Sm.					R			R						
smithii var. amphicephala Grun.			R										R	
var. lacustris Grun.			R											
Melosira ambigua (Grun.) O. Müll.			R											
granulata (Ehr.) Ralfs		A		U										
Meridion circulare (Grev.) Ag.	U	R	U	U		R		R						
Navicula* abiskoensis Hust.			R					R						
*capitata Ehr.												R	R	
*var. hungarica (Grun.) Ross													R	
cuspidata (Kütz.) Kütz.			R							R				
gastrum (Ehr.) Kütz.				R										
*halophila f. subcapitata Østrup?				R										
heufleri Grun.						U								
*var. leptocephala (Bréb. ex Grun.) Patr.				R										
lanceolata (Agardh) Kütz.													R	
*nigrii De Notaris										R				U
oblonga Kütz.	U		U			R							R	
*placentula var. rostrata Mayer												R	R	
*pseudoventralis Hust.												R		R
pupula Kütz.	R	R	R	U		U			U	R	U	U	U	
var. capitata Skv. & Meyer									U					
pupula Kütz. var.?												U	R	
radiosa Kütz.	C	U	U	U	R	R		R		R	R			R
*var. parva Wall.			R											
var. tenella (Bréb. ex Kütz.) Grun.	U	U	C	U	R	U	R	U	C	U	U	R	U	R

salinarum var. intermedia (Grun.) P. T. Cl.				R		R								
tripunctata (O. Müll.) Bory				R					R	R				
*wittrockii (Lagerst.) A. Cl.								R		R				
Neidium affine (Ehr.) Pfitz.	R		R						R					
*var. amphirhynchus (Ehr.) P. T. Cl.			R											
productum (Wm. Sm.) P. T. Cl.											R			
Nitschia* acicularioides Hust.	R	C	R	R					R					
acicularis (Kütz.) Wm. Sm.		U	R											
amphibia Grun.	U	U	C	R	R			R	U	U	U	U	U	U
angustata (Wm. Sm.) Grun.	R			U										
var. acuta Grun.														R
dissipata (Kütz.) Grun.		R	U	U										
*graciloides Hust.				U				R						
linearis (Ag.) Wm. Sm.	U	U		U		R				R				
palea (Kütz.) Wm. Sm.	R			U		R			U					
*recta Hantz.				U						R				
sigmoidea (Nitz.) Wm. Sm.	U			C		R		R			R			
*subtilioides Hust.		U	U	C	R				R	R				
*tropica Hust.								R						
Pinnularia biceps Greg.				R										
*brebissonii f. biundulata (O. Müll.) A. Cl.							U			U				
viridis (Nitz.) Ehr.		R	R							R				
Rhoicosphenia curvata (Kütz.) Grun. ex Rabh.				U										
Rhopalodia gibba (Ehr.) O. Müll.	R	R		R										
Stauroneis* acuta var. terryana Temp. ex P. T. Cl.			R											
anceps Ehr.		R	R			R		R	R			R	R	R
anceps f. linearis (Ehr.) Hust.	R								R					
phoenicenteron (Nitz.) Ehr.										R		R		
f. gracilis (Ehr.) Hust.			R										R	
Stephanodiscus astrea (Ehr.) Grun.		U												
var. minutula (Kütz.) Grun.			C											
Surirella angusta Kütz.				R										
linearis var. constricta (Ehr.) Grun.		R												
Synedra acus Kütz.	C	R	C				R		R					
amphicephala Kütz.			U		U	R		R		R				
capitata Ehr.			R											
*delicatissima var. angustissima Grun.					R			R						
parasitica (Wm. Sm.) Hust			R	R								U	R	
*var. subconstricta (Grun.) Hust.				R									R	
radians Kütz.	C	C		A	U	U	C	R		U			R	R
*rumpens var. scotica Grun.											R			
ulna (Nitz.) Ehr.	U	U	U	U	U			R						R
Tabellaria fenestrata (Lyngb.) Kütz.		C	C	U	U	R	C	U	U	R	U	C	R	R
flocculosa (Roth) Kütz.		U												

determine which it prefers. The temporal distributions of these taxa are illustrated in Figure 2.

Samples from the epiphytic communities revealed 88 taxa. Of these the following seem to prefer an epiphytic existence by virtue of their frequency as epiphytes and their infrequency in other communities: *Achnanthes lanceolata, A. minutissima* (see above discussion), *Cymbella delicatula,* and *C. microcephala.*

Epipelic samples exhibited the least diversity (66 taxa). With the possible exception of *Fragilaria leptostauron,* no diatom species appeared to demonstrate a preference for epipelic habitats. However, because of the morphometry of Tiplady Bog, there is virtually no shallow littoral zone and epipelic samples had to be collected from fairly deep water. It seems quite possible under these circumstances that thriving epipelic diatom populations might be diluted by the constant "rain" of empty or dying diatom frustules from other habitats, particularly plankton. Relative cell counts would not expose the habitat preference of such populations unless they appeared exclusively in the epipelon.

The most abundant planktonic taxa in Tiplady Bog, those illustrated in Figure 2, also exhibit a ubiquitous worldwide distribution and are frequently found in great numbers (Lowe, 1974; Hustedt, 1930). *Achnanthes minutissima* and *Melosira granulata* are truly cosmopolitan, present throughout a wide range of pH. Cholnoky (1968) indicates that *A. minutissima* grows best at a pH of 7.5 to 7.8, nearly identical to the surface pH range found in Tiplady Bog. Hustedt (1930) states that *M. granulata* is commonly found in massive amounts particularly in the summer months, as is further illustrated by its August peak in the Tiplady Bog plankton. *C. kützingiana* and *C. comta* are often abundant in freshwater lakes and ponds, both exhibiting an indifference

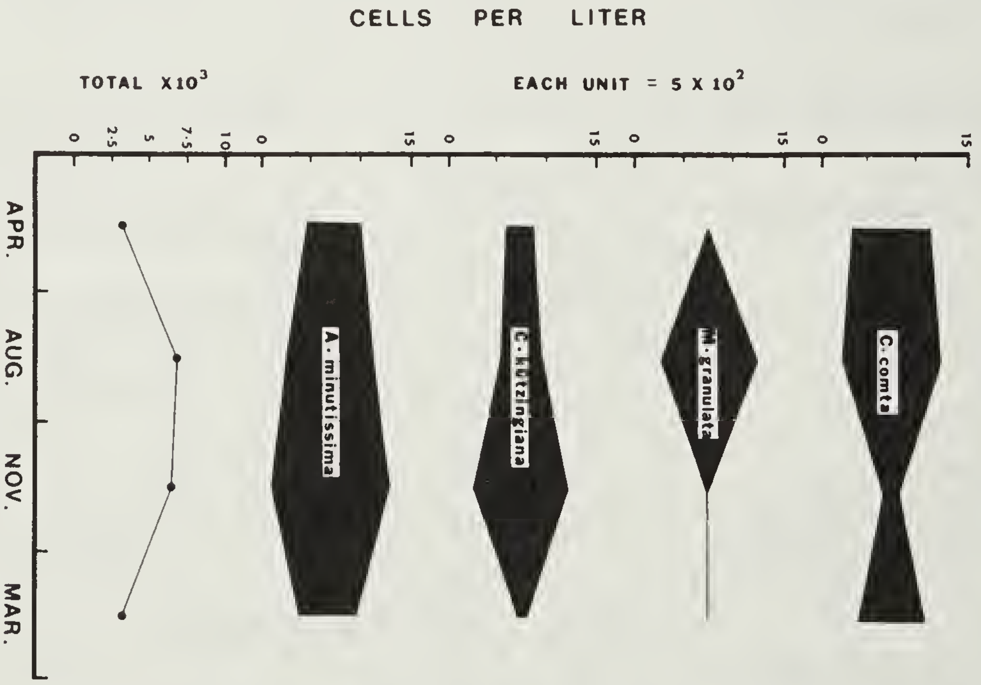

Fig. 2. Total planktonic diatom cells per liter and the temporal distribution of four abundant planktonic species (1974-75): *Achnanthes minutissima, Cyclotella kützingiana, C. comta,* and *Melosira granulata.*

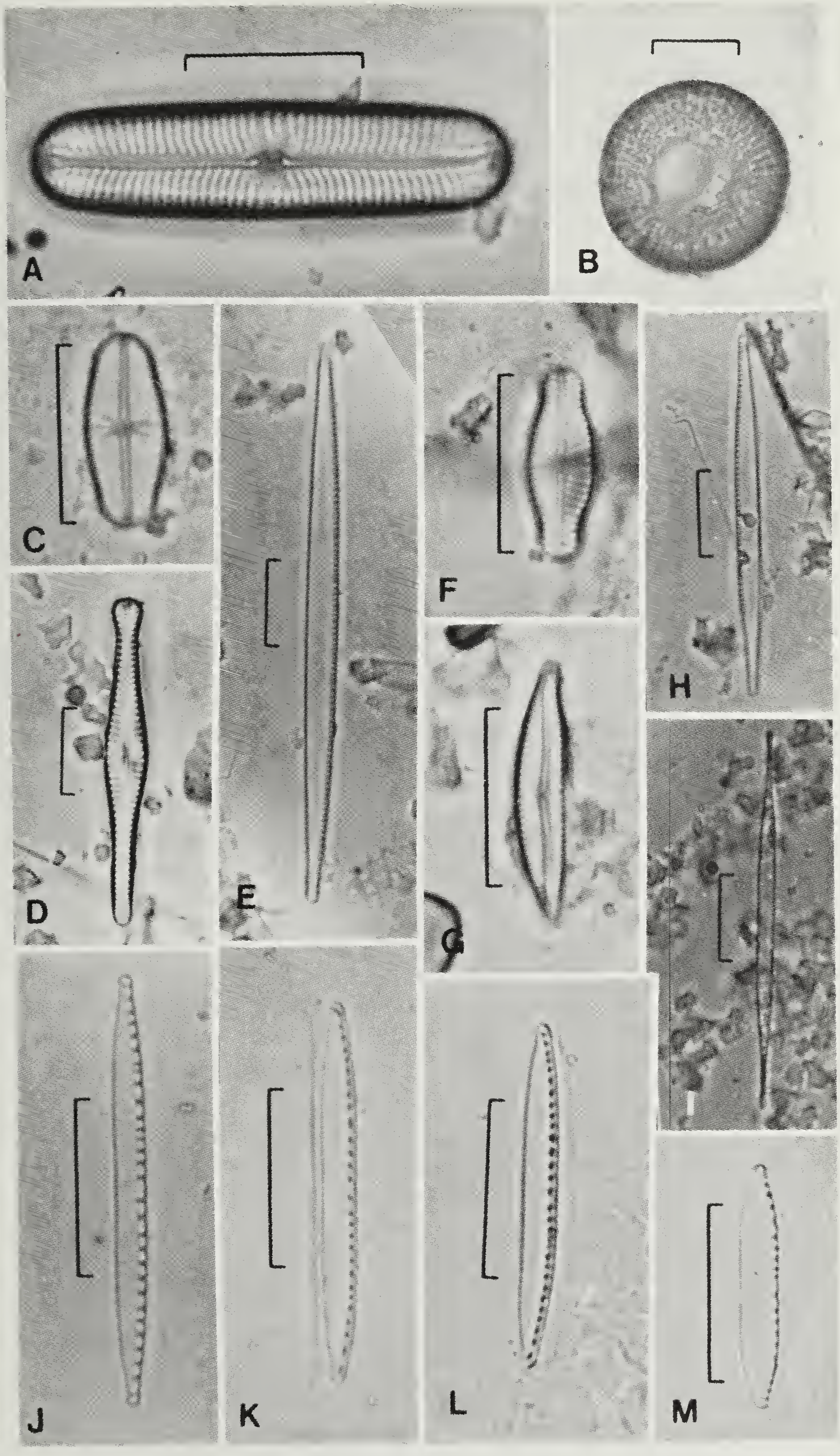

Fig. 3. A. *Navicula wittrockii*; B. *Cyclotella* sp. #1. C. *Navicula pupula* var. ? D. *Gomphonema subtile* f. *angusta*. E. *Nitzschia subtilioides*. F. *Navicula pseudoventralis*. G. *Cymbella ruttneri*. H. *Nitzschia graciloides*. I. *Nitzschia acicularioides*. J-M. Variation in *Nitzschia tropica*. (Scales equal 10 μm).

to salinity. *C. comta* is most frequent in alkaline environments, while *C. kützingiana* is relatively indifferent to pH, again consistent with their presence in Tiplady waters.

Some diatoms not included in more widely used taxonomic references (Hustedt, 1930; Patrick & Reimer, 1966, 1975) have been illustrated in Figure 3.

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NEW OR NOTEWORTHY TAXA FOR CENTRAL WISCONSIN IN THE FLORA OF THE "WHITING TRIANGLE"

Robert W. Freckmann
Department of Biology and Museum of Natural History
University of Wisconsin–Stevens Point 54481

The village of Whiting adjoins the city of Stevens Point in Portage County, Wisconsin, and lies 12 km southeast of the geographic center of the state, on sandy glacial outwash 16 km west of the terminal moraines and 24 km north of the bed of Glacial Lake Wisconsin. It is in the Tension Zone of Curtis (1959), where the ranges of many species of the prairies and hardwood forests of southern Wisconsin meet those of the conifer–hardwood forests of northern Wisconsin (Fig. 1 & 2). The terrain within 15 km is nearly flat and most of the soils are sandy and drought prone (Soil Conservation Service, 1971). The pre-settlement vegetation probably consisted of a mixture of sandy prairie and oak savanna in the immediate area with large marshes to the south and mixed forests dominated by white pines along the Wisconsin River and to the north (Roth, 1898, Catenhusen, 1944, 1950; Rosholt, 1959). Most of the land is now in agriculture or towns, but bands of undeveloped land persist along rivers, railroad tracks, and elsewhere. The undeveloped uplands are generally sandy sites often dominated by Hill's oak *(Quercus ellipsoidalis)* or jack pine *(Pinus banksiana)*. Lowland sites are more variable in nature.

The Stevens Point area had received little attention from botanists before 1964 when a Portage County flora project was begun. The herbarium of the University of Wisconsin–Stevens Point now includes about 30,000 sheets collected within a 40 km radius, primarily since 1969. One of the results of the recent field work has been the realization that one small area, referred to locally as the Whiting Triangle, supports a large flora with a notable number of species not previously reported for this part of Wisconsin.

The Whiting Triangle is located in the village of Whiting in section 9, T23N, R8E. It consists of a triangular plot of about 30 acres bounded by railroad tracks, a paper mill, a village park, and the confluence of the Wisconsin and Plover Rivers. All of the area is disturbed to some extent by foot traffic and by motor cycles or trail bikes. Some of the open sandy areas have been scraped and levelled by bulldozers at least twice in the last 15 years. The major habitats include recently disturbed areas of nearly pure sand; a moderately disturbed sandy prairie relic; a sandy upland woods of Hill's oak *(Quercus ellipsoidalis)* and jack pine *(Pinus banksiana)*; a marsh with large clumps of cattails *(Typha latifolia)*; a low sandy area varying from inundated to dry during the growing season; a small slough with permanent standing water; the bank of the Plover River dominated by alder *(Alnus rugosa),* willows (*Salix* spp.), and dogwoods (*Cornus* spp.); a floodplain woods along the Wisconsin River, dominated by river birch *(Betula nigra),* cottonwood *(Populus deltoides),* silver maple *(Acer saccharinum),* and black ash *(Fraxinus* *nigra);* and a moist woods dominated by red maple *(Acer rubrum),* paper birch *(Betula papyrifera),* yellow birch *(B. lutea),* and hemlock *(Tsuga canadensis).*

The Whiting Triangle has been observed and collected fairly continuously since 1964. Voucher specimens are on file at UWSP for nearly all of the species recorded for this site. The majority of the collections were made by the author between 1972 and 1974. Other collections were made by Robert S. Whitmire in 1964 and 1965, George C. Becker in 1965, and Mark Phillips in 1974. A checklist of all taxa recorded for this area is available on request from the author. Most of the data cited for the distribution of species in Wisconsin have been obtained from the files of Theodore S. Cochrane of the University of Wisconsin–Madison. Most of the grasses noted in this paper have been reported previously for central Wisconsin (Freckmann, 1972).

COMPOSITION OF THE FLORA

The vascular flora of the Whiting Triangle, ignoring the weedy fringes, consists of 408 species, including six species represented by two subspecies or varieties. In addition, four putative interspecific hybrids have been found, bringing the total flora of the area to 418 taxa. Approximately 364 species in this flora are native to the United States and approximately 355 are native to Wisconsin (relying primarily on Fernald, 1950, as the authority on the area of origin for each species).

Many of the species at this site are plants of southern and southwestern Wisconsin which Curtis (1959) cited as indicators of southern elements reaching their limits in the Tension Zone. A remarkable number of these southern Wisconsin species reach the northern limit of their ranges in central Wisconsin at this site, although some occur on prairie relics within a few kilometers to the south or west. The list includes sand milkweed *(Asclepias amplexicaulis),* butterfly weed *(A. tuberosa),* hairy grama grass *(Bouteloua hirsuta),* white upland aster *(Aster ptarmicoides),* tickseed *(Coreopsis palmata),* white wild indigo *(Baptisia leucantha),* yellow stargrass *(Hypoxis hirsuta),* stiff goldenrod *(Solidago rigida),* and prairie dropseed *(Sporobolus heterolepis).* These are all fairly common in a disturbed sandy prairie dominated by little bluestem *(Schizachyrium scoparium),* porcupine grass *(Stipa spartea),* big bluestem *(Andropogon gerardii),* and Indian grass *(Sorghastrum nutans).*

The following 11 species also reach their northern limits in central Wisconsin at the Whiting Triangle, but most of these are not known from other sites within at least 20 km: early tickle grass *(Agrostis hyemalis),* bank cress *(Arabis laevigata),* triple awn grass *(Aristida intermedia),* sea-beach needlegrass *(A. tuberculosa),* Japanese brome *(Bromus japonicus),* hair sedge *(Bulbostylis capillaris),* sand evening primrose *(Oenothera rhombipetala),* bead grass *(Paspalum ciliatifolium),* large-flowered beard tongue *(Penstemon bradburii),* slender beard tongue *(P. gracilis),* and purple sand grass *(Triplasis purpurea).* These species are sporadic to fairly common in the disturbed sandy areas which also support most of the rare or disjunct species discussed below.

Three additional species reach their northern limits in central Wisconsin here, but in the wet woods. Ellisia *(Ellisia nyctelea)* and pellitory *(Parietaria pensylvanica)* are of sporadic occurrence here and in semi-open woods southward in Wisconsin. River birch *(Betula nigra)* is one of the dominant trees of the floodplain woods with an essentially continuous range southward along the Wisconsin River. Its range apparently ends abruptly along the River at this point.

RARE OR DISJUNCT SPECIES

The majority of the species at the Whiting Triangle which are either rare in Wisconsin or disjunct to this site by distances of 100 km or more occur on the open, disturbed sandy sites within 100 m of the railroad tracks. This habitat has been kept open to plant colonization for 16 years or more, resulting originally from levelling and bulldozing to prepare the area as an industrial building site. Grasses, sweet fern *(Comptonia peregrina),* and blackberries (*Rubus* spp.) had stabilized the sand and covered most of the exposed areas by 1974. Since then, further bulldozing and greatly increased use of the area by trail bikes again opened large patches of nearly pure sand. The population sizes of some of the species listed below fluctuated substantially during at least the last seven years but all have persisted. The past year, 1976, brought the greatest decrease in their numbers, probably because of a combination of trail bike disturbance and a severe mid-summer drought.

The dominant species in this area of partially stabilized sands include sweet fern, small triple awn grass *(Aristida basiramea),* poverty oatgrass *(Danthonia spicata),* Junegrass *(Koeleria macrantha),* fly-away grass *(Agrostis scabra),* poverty grass *(Sporobolus vaginiflorus),* sand dropseed *(S. cryptandrus),* side-oats grama grass *(Bouteloua curtipendula),* winged pigweed *(Cycloloma atriplicifolia),* cottonweed *(Froelichia floridana),* and western ragweed *(Ambrosia psilostachya).* The more noteworthy species associated with these are listed below:

Prairie trefoil *(Lotus purshianus–Hosackia americana* in some references) occurs in a small population of about a dozen individuals near the railroad tracks. The population has been observed for the last five years. The only previous record of this species for Wisconsin is from Edgar, Marathon Co. (MIL, WIS), collected from a railroad right-of-way by Charles Goessl in 1915.

Western spiderwort *(Tradescantia occidentalis)* is represented by a few plants scattered in a more stable area of sandy soil. This population has remained of constant size from 1972 through 1976. All previous records are from the northwestern border of Wisconsin, at least 190 km away.

Wild begonia *(Rumex venosus)* was abundant in most of the open area of sand through 1974 but has declined in the past two years to about 10 individuals. The only previous collections (WIS) of this species in Wisconsin are from Columbia and Dane Counties.

Western wallflower *(Erysimum asperum)* was abundant throughout the sandy area through 1975 but became rare in 1976. This is the fourth record

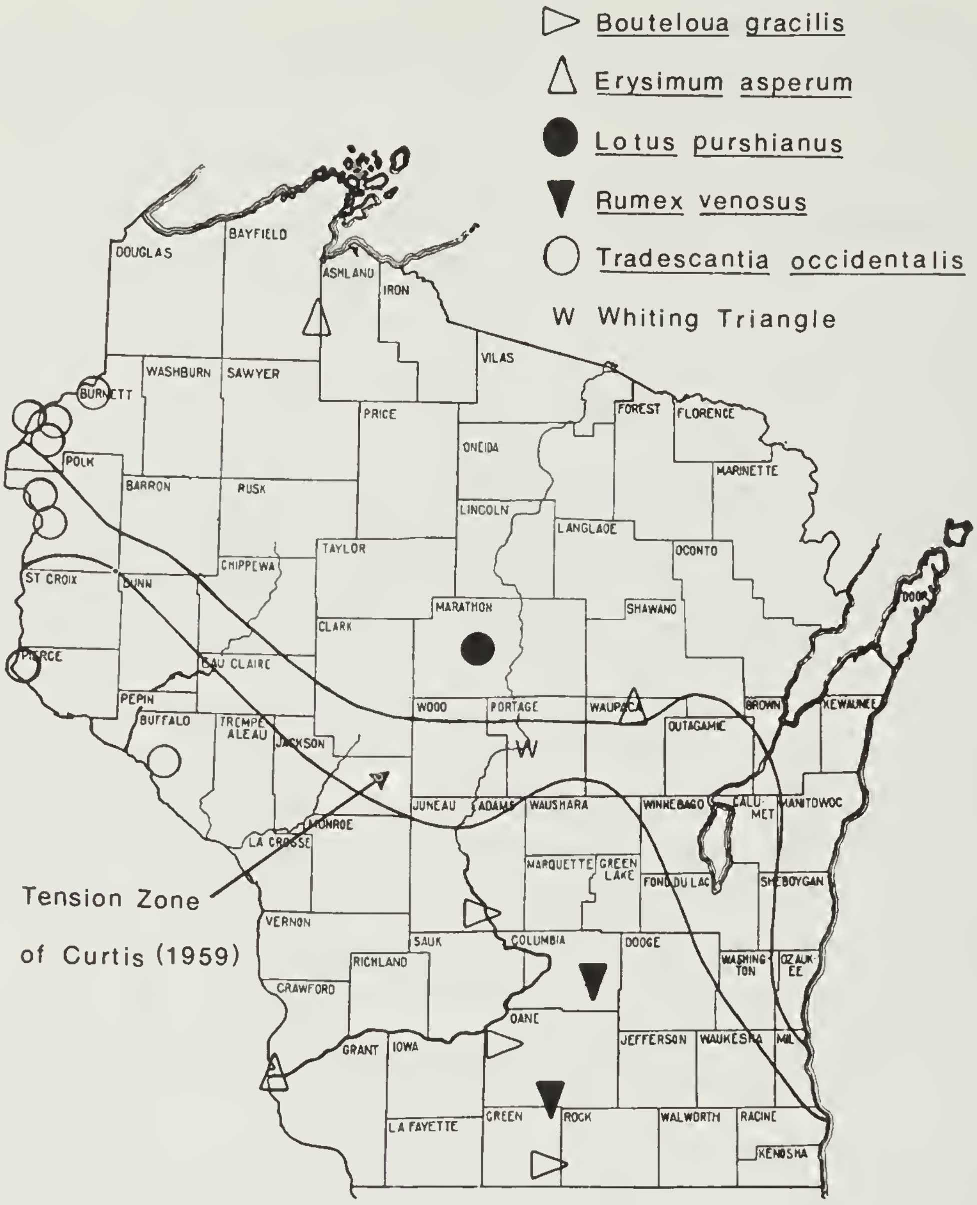
▷ Bouteloua gracilis
△ Erysimum asperum
● Lotus purshianus
▼ Rumex venosus
○ Tradescantia occidentalis
W Whiting Triangle
Tension Zone of Curtis (1959)
DOUGLAS
BAYFIELD
ASHLAND
IRON
VILAS
WASHBURN
SAWYER
BURNETT
PRICE
ONEIDA
FOREST
FLORENCE
MARINETTE
POLK
BARRON
RUSK
LINCOLN
LANGLADE
OCONTO
TAYLOR
CHIPPEWA
ST CROIX
DUNN
MARATHON
SHAWANO
DOOR
CLARK
PIERCE
EAU CLAIRE
PEPIN
WOOD
PORTAGE
WAUPACA
BROWN
KEWAUNEE
BUFFALO
TREMPEALEAU
JACKSON
OUTAGAMIE
JUNEAU
ADAMS
WAUSHARA
WINNEBAGO
CALUMET
MANITOWOC
MONROE
LA CROSSE
MARQUETTE
GREEN LAKE
FOND DU LAC
SHEBOYGAN
VERNON
SAUK
COLUMBIA
DODGE
WASHINGTON
OZAUKEE
RICHLAND
CRAWFORD
DANE
GRANT
IOWA
JEFFERSON
WAUKESHA
MIL
LA FAYETTE
GREEN
ROCK
WALWORTH
RACINE
KENOSHA

Fig. 1. The distribution in Wisconsin of some of the rare species which occur at the Whiting Triangle.

for it in the state. Two other wallflowers *(E. cheiranthoides* and *E. inconspicuum)* grow with it here.

Needle grass *(Stipa comata)* is scattered along the railroad tracks. This is the ninth known location for it in Wisconsin.

Feather bunchgrass *(Stipa viridula)* is well-established here and also along sandy railroad right-of-ways for a few km to the southwest. This is the eighth collection in the state, 100 km or more north of all previous collection sites.

Clammyweed *(Polanasia dodecandra)* is abundant on sandy soil here and in the vicinity. It is common and well-collected in southern and western Wisconsin, but this site is more than 110 km north and 70 km east of these sites.

Wild licorice *(Glycyrrhiza lepidota)* is common along the margin between the open sand and an invading thicket of sweet fern, poison ivy *(Toxicodendron radicans* var. *rydbergii),* and blackberries. Licorice seems to be well established along the Mississippi River in populations which may be native. It is rare and probably adventive elsewhere in the state, with other records from Bayfield, Dane, Milwaukee, and Shawano Counties.

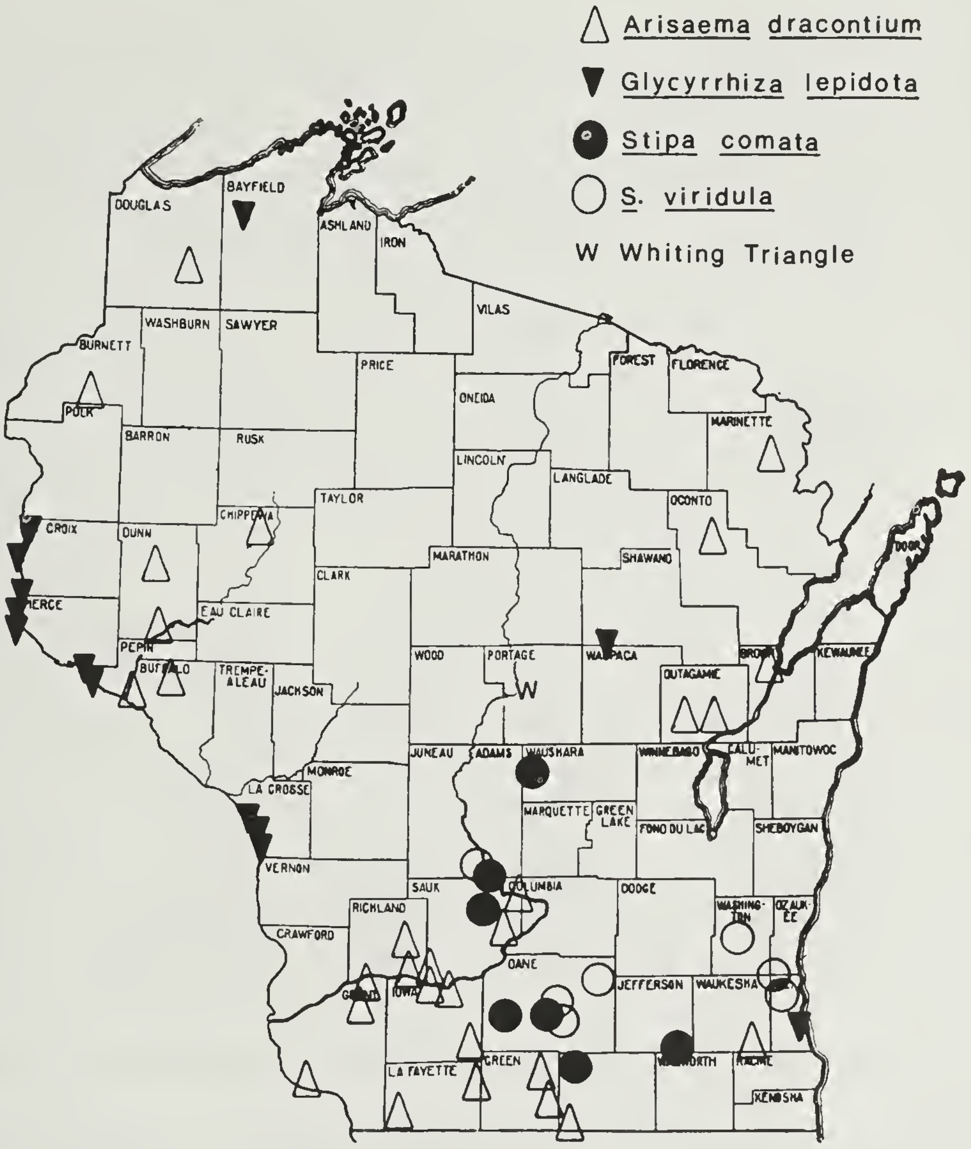
△ Arisaema dracontium
▼ Glycyrrhiza lepidota
● Stipa comata
○ S. viridula
W Whiting Triangle
DOUGLAS
BAYFIELD
ASHLAND
IRON
VILAS
WASHBURN
SAWYER
BURNETT
PRICE
FOREST
FLORENCE
ONEIDA
POLK
BARRON
RUSK
MARINETTE
LINCOLN
LANGLADE
TAYLOR
CHIPPEWA
OCONTO
CROIX
DUNN
MARATHON
SHAWANO
DOOR
CLARK
ERCE
EAU CLAIRE
PEPIN
BUFFALO
TREMPEALEAU
WOOD
PORTAGE
WAUPACA
OUTAGAMIE
BROWN
KEWAUNEE
JACKSON
W
JUNEAU
ADAMS
WAUSHARA
WINNEBAGO
CALUMET
MANITOWOC
MONROE
LA CROSSE
MARQUETTE
GREEN LAKE
FOND DU LAC
SHEBOYGAN
VERNON
SAUK
COLUMBIA
DODGE
WASHINGTON
OZAUKEE
RICHLAND
CRAWFORD
DANE
JEFFERSON
WAUKESHA
GRANT
IOWA
GREEN
LA FAYETTE
WALWORTH
RACINE
KENOSHA

Fig. 2. The distribution in Wisconsin of additional rare species which occur together at the Whiting Triangle. Both maps (fig. 1 & 2) are based on distribution maps prepared by Theodore S. Cochrane of the University of Wisconsin, Madison.

The sandy area on lower ground which is partially under water in the spring and moderately dry in late summer also supports some rare or notable plants. Blue lettuce *(Lactuca pulchella)* was known previously only from southeastern Wisconsin (Johnson & Iltis, 1964), and the population here represents a range extension of 120 km. Bartonia *(Bartonia virginica)* and unicorn-root *(Aletris farinosa),* two "Coastal Plain" species, grow here and at a few other sites in central Wisconsin. Two species of knawel *(Scleranthus annuus* and *S. perennis)* occur here and have become common in central Wisconsin in recent years but were scarcely known from the northeastern quarter of the United States before the mid-1960's.

Green dragon *(Arisaema dracontium)* is fairly common on the Wisconsin River flood plain at the south end of the Triangle. Its range extends well north in Wisconsin on both the eastern and western sides of the state, but it is not known otherwise from the center of the state north of Columbia County, 100 km to the south. This may be the same population reported (but not collected) by L. S. Cheney in 1894 (Cheney, 1899) from the first botanical exploration of north-central Wisconsin. If so, the population has been re-discovered in the present study after nearly 70 years.

Three possible hybrid populations also occur here. The most abundant hybrid swarm is well-known in central Wisconsin in sandy fields. It involves the slender-stemmed galingale *(Cyperus lupulinus)* and Schweinitz's umbrella sedge *(C. schweinitzii)* with the entire array of intermediates described by Marcks (1974) represented. A hybrid between bracted plantain *(Plantago aristata)* and woolly plantation *(P. patagonica),* perhaps referable to *P. spinulosa,* is scattered along the railroad tracks with both putative parents. Tessene (1968) suggested that a few Wisconsin specimens show indications of introgressive hybridization between the two species, but he cited no examples of suspected F_1 hybrids. None of the specimens from the Triangle are exactly intermediate between the parent species but tend to resemble *P. patagonica*–the more common species here–more closely.

The third putative hybrid may be referred to *Lysimachia* X *conmixta,* a hybrid between swamp candles *(L. terrestris)* and tufted loosestrife *(L. thyrsiflora).* Ray (1956) had cited two collections of *L. conmixta* by Schallert (DUKE) for Wisconsin. Iltis & Shaughnessy (1960) questioned the claim that these specimens represented hybrids, stating that one of the two specimens *(Schallert 765)* was only a slightly abnormal *L. thyrsiflora;* the other *(Schallert 74)* was conceded to be somewhat intermediate between the putative parents. However, they further stated that "except for the extra inflorescence most of the specimens cited by Ray from other states do not deviate in any apparent morphological way from typical single-racemed plants of *L. terrestris.*"

Five species of loosestrife occur in the Whiting Triangle. Two of these, fringed loosestrife *(L. ciliata)* and lanceleaf loosestrife *(L. lanceolata),* do not seem to be involved in the formation of the hybrids. Whorled loosestrife *(L. quadrifolia)* is common here on moist sandy soil. About 10 plants of swamp candles are scattered on a small mudflat at the edge of a slough adjacent to the whorled loosestrife population. A few plants of tufted loosestrife grow in about 2–5 cm of water in the same shallow slough. The *L. conmixta* population occupies a narrow band of wet sand on the opposite side of the slough. This habitat was created in 1969 when a hill of very sandy soil was leveled by a bulldozer with some of the nearly pure sand of the subsoil being pushed into the slough. The hybrids were first observed in 1971. The hybrid population now consists of about six individuals. Some of the roots and rhizomes of the hybrids grow below water in the slough, but the aerial stems generally arise in the sand a few centimeters above the water table. Wood horsetail *(Equisetum sylvaticum)* is common in this same band and is almost the only species associated with it.

The putative hybrid combines many of the features of swamp candles and tufted loosestrife as indicated in Table 1, but it also suggests some relationship to whorled loosestrife by the presence of some solitary axillary inflorescences, the septate hairs on the stem, and the choice of habitat which is more dry and sandy than that of swamp candles or tufted loosestrife. In mid-June the hybrids superficially resemble tufted loosestrife more than the other species because at this time most of the inflorescences consist of axillary racemes

TABLE 1. Comparison of *Lysimachia* X *conmixta* (*L. terrestris* X *L. thyrsiflora*) based on 4 specimens from the Whiting Triangle with all specimens of related *Lysimachia* species in the UWSP herbarium collected within a 15 km radius of the Whiting Triangle: *L. quadriflora,* 8 specimens; *L. terrestris,* 8 specimens; and *L. thyrsiflora,* 7 specimens. Pollen data are based on 200 grains/slide from 4 individuals of each of the 4 taxa.

	L. conmixta	*L. quadrifolia*	*L. terrestris*	*L. thyrsiflora*
No. of leaves/node	2	4-6	2	2
Leaf length (mm) (largest leaf)	62-105	31-45	48-64	77-150
Leaf width	21-30	10-22	7-11	11-27
Inflorescences:				
Solitary, axillary	+	+	0	0
Axillary raceme	+	0	0	+
Terminal raceme	+	0	+	0
No. of corolla lobes	5-9	5	5	7-9
Stamen number	5-9	5	5	7-9
Glands on filaments	0	+	+	0
Pollen:				
Size range (μ)	20.0-38.8	21.3-22.5	22.5-26.3	21.2-22.6
Avg. diameter (μ)	28.2	21.9	23.5	21.7
Fertility range	15-27%	92.5-95.5%	88-91.5%	84.5-88%
Fertility avg.	20.6%	94.1%	90.0%	86.3%

with flowers crowded toward the top of the peduncle-rachis. The presence of many flowers with six to nine stamens and corolla lobes and the absence of glands on the stamen filaments heighten the resemblance. However, by July and August many of the lower lateral inflorescences have dropped off, and the more open terminal raceme with large bracts and smaller sub-terminal lateral racemes suggest swamp candles specimens.

The hybrid population could represent a hybrid between tufted loosestrife and a population of swamp candles which carries some traits of whorled loosestrife through introgressive hybridization. Cooperrider & Brockett (1974, 1976) presented evidence that swamp candles and whorled loosestrife hybridize throughout the area of overlap of their ranges. They cited four Wisconsin localities for this hybrid (called *L.* X *producta*) including two from within 40 km of the Whiting Triangle. They also indicated that some specimens suggest the possibility of backcrosses or introgression of *L. producta* to either parent species. In any case, putative *L. conmixta* plants at the Whiting Triangle cannot be dismissed as slightly abnormal swamp candles. The probable hybrid nature of the plants is reinforced by the low pollen fertility (15–27%) as indicated by shape and stainability in cotton-blue in lactophenol, and by the irregular sizes and shape of the grains. These observations closely agree with those of Marie-Victorin (1913) on other putative *L. conmixta* plants.

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TREE POPULATIONS OF A MATURE ASPEN FOREST IN CHEBOYGAN COUNTY, MICHIGAN

James R. Wells
Cranbrook Institute of Science
Bloomfield Hills, Michigan, 48103

A history of botanical field activity in the Cheboygan County region has been prepared by Voss (1956), who reviewed the lumbering activities which date from 1844, although a peak in cutting of timber was not achieved until very late in the century. A number of major fires followed lumbering. Vast areas altered by cutting and burning were pioneered by aspens. Several workers, some dating back to 1909, have investigated stands of aspen in the environs of the University of Michigan Biological Station; their publications are listed by Benninghoff and Cramer (1963). This report is intended to characterize in detail for the year 1976 the arboreal composition of a mature large-toothed aspen (*Populus grandidentata*) forest in Cheboygan County, in the upper part of Michigan's lower peninsula, and to establish base-line information for future measurements showing the rate of change as this forest plot is succeeded by a climax forest type. Since the study area is located within the boundaries of the University of Michigan Biological Station at Douglas Lake, its security is enhanced for future long-term comparisons. The widely recognized label for climax forest type in this region is northern hardwoods with hemlock and white pine (Braun, 1950).

Although most of the data given here represent but a single year, 1976, other data collected for the two previous years were useful in refining maps and checking identifications. The data were collected in mid-January and mid-March, for the most part by high school students from Cranbrook School and Kingswood School. (Both schools are part of the Cranbrook Educational Community.)

From the more than 9000 acres forming the University of Michigan Biological Station property this study area of approximately two acres was selected because it represents a mature stand of large-toothed aspen being succeeded by several hardwood species. We hope to have arrived in time to begin monitoring in some detail the rate of change from one mature forest type to another. Additional monitoring efforts are planned at least every five years for the forseeable future.

Increment core samples of selected large-toothed aspens indicate ages on the order of 50 to 60 years. This age is probably an average maximum at these latitudes for this species. Presumably little disturbance has occurred since lumbering activities and fires at least 50 years ago.

The study area is located in Cheboygan County, T37N, R3W, Sec. 31, along Bryant Road's west side approximately 0.1 mile north of the intersection of Riggsville and Bryant Roads. The eastern boundary of the study area lies about 10 meters interior to the forest's eastern margin and extends in

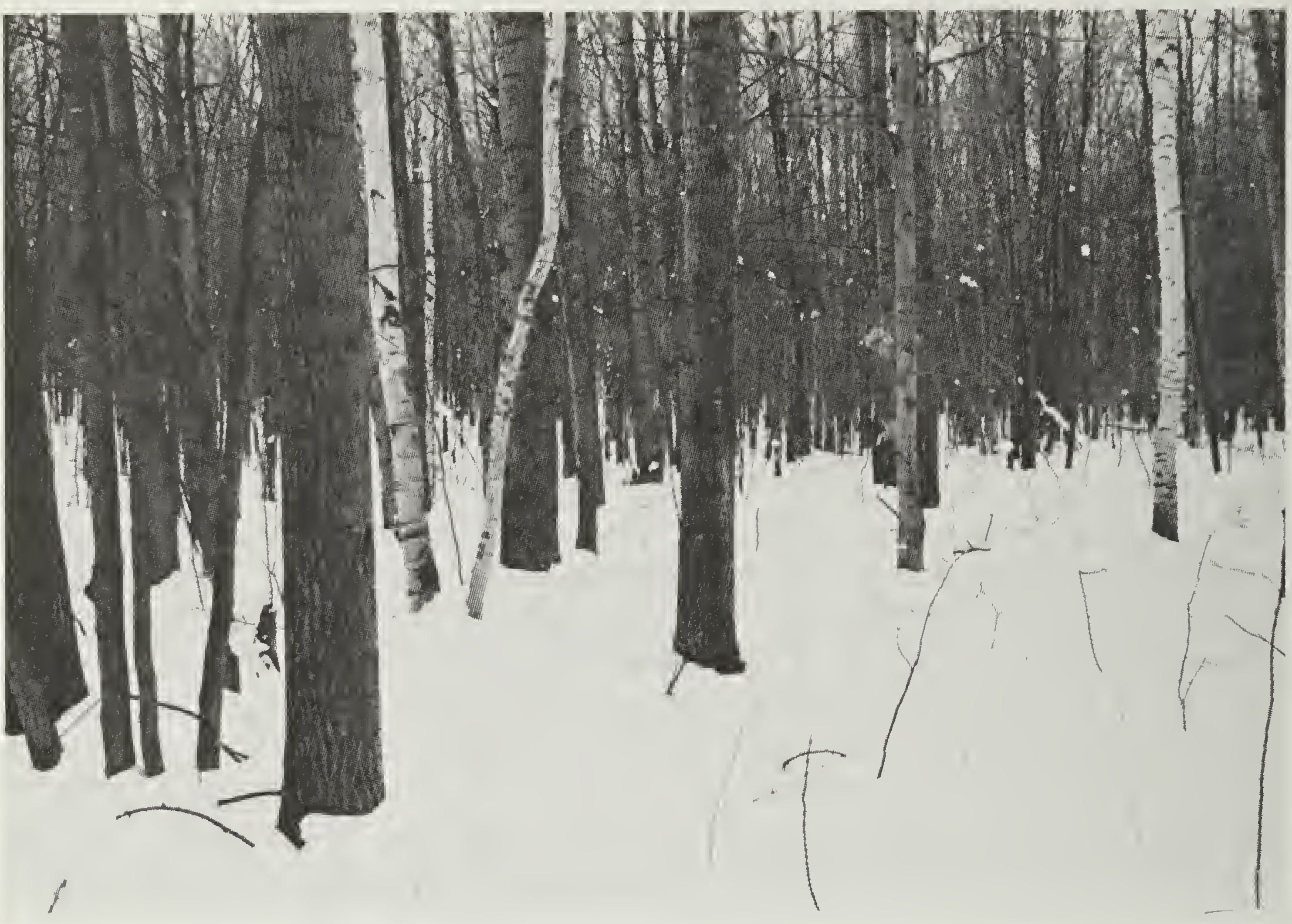

Fig. 1. View of large-toothed aspen forest, looking west from plot 9E, Jan. 20, 1975.

a N–S direction at a variance of approximately 11° from magnetic north. The boundaries selected offered few obstructions by trees in establishing the perimeter. No trees were removed in laying out the study area.

A transit was used to delineate the 10,000 meter^2 area which was then divided into 100 quadrats whose sides each measured 10 meters. Brightly painted concrete reinforcing rods 1 cm in diameter by 1.3 m long were driven half way into the soil for corner markers of each quadrat. Aluminum tags with engraved numbers and letters were attached to the northeast stake of each quadrat. The rows A through J extend in a N–S direction while columns 1 through 10 are in an E–W direction.

The study area is level to undulating with a maximum of about two meters variation in elevation. Sloping occurs at the southwest corner, where seasonally swampy conditions may prevail, and at the higher, sandy northeastern sector of the northern border. A number of small depressions (e.g., about 1 meter deep and 2-3 meters wide) scattered over the area occasionally become partially filled with water. These depressions are often conspicuous by their paucity of vegetation.

A total of six soil samples were taken at random using a tubular sampler whose inside diameter measured 2 cm and which delivered a 15 cm cylinder of soil. These August 1975 samples obtained from plots 4A, 8A, 5C, 3H, 7H, and 8J, were analyzed by the Soil Testing Laboratory of Michigan State

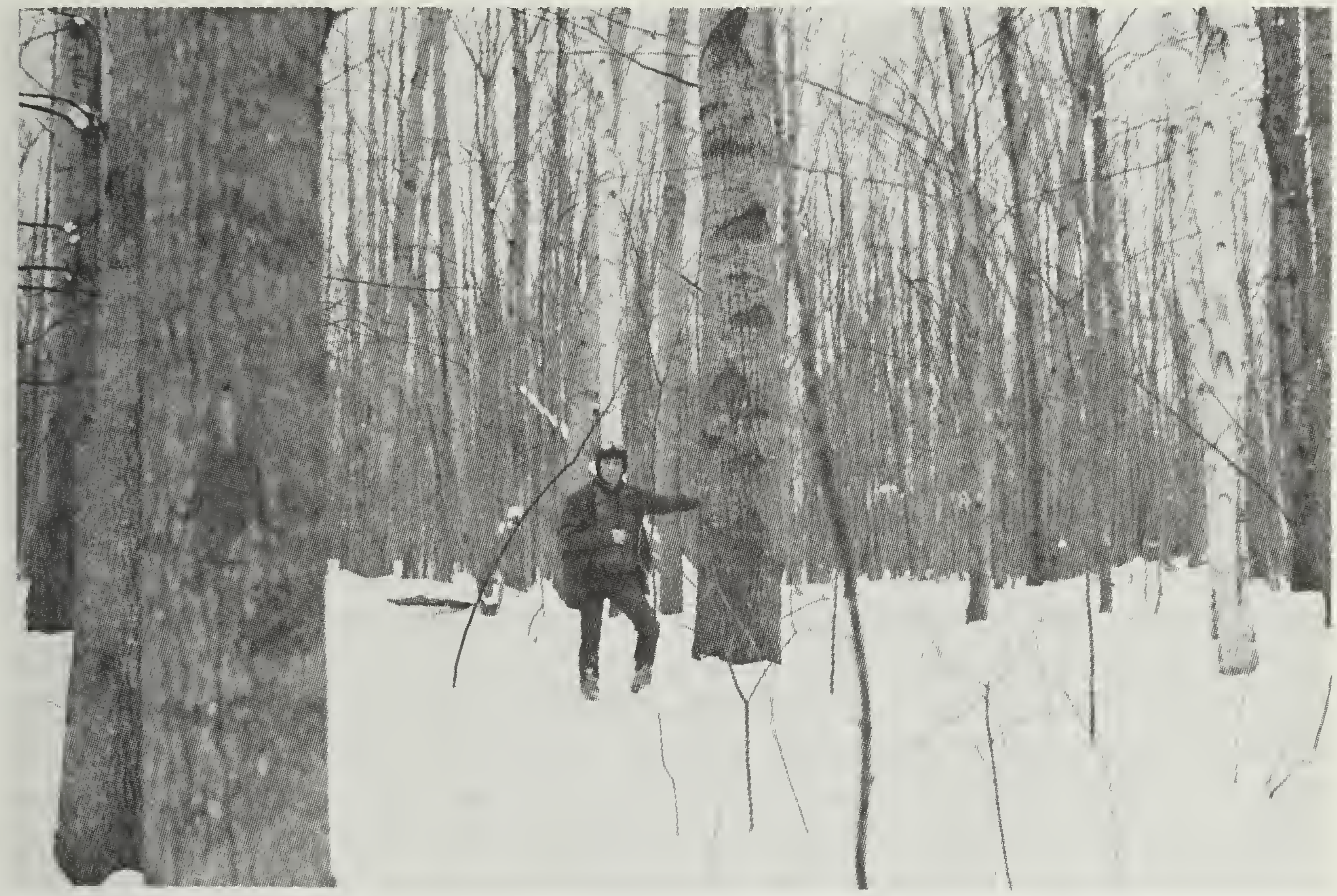

Fig. 2. View from study plot 8H showing large-toothed aspen 21.3″ DBH, Jan. 20, 1975.

University. The pH measurements ranged from 5.1 to 6.4. Soil pH near the largest large-toothed aspen which is located in plot 7H was 6.4 while a pH of 6.0 was recorded for soil near the largest *Acer pensylvanicum* (striped maple) located in plot 8A.

The soil in the study area is of the Rubicon-Grayling Association, according to the District Conservationist, Walter J. Messer (pers. comm.), but portions of Cheboygan County including the study area have not yet been mapped. Rubicon soils are formed in deep sands. Beneath the forest litter is a black surface layer with a light, brownish-gray, subsurface sandy layer approximately 15 cm (6 in.) in thickness. The subsoil is very friable, brown to yellowish-brown, and about 76 cm (30 in.) thick. Underlying materials are on till, beach ridges, sand dunes, and outwash plains (1939, USDA). Soil fertility tends to be low, and drainage is generally good.

The summers are short and cool to moderately warm, and winters are long. The frost-free growing season averages 86 days annually. The average last date for frost in spring is June 6 while the average first date of fall frost is September 1. Precipitation averages 79 cm (31 in.) annually and is approximately equally distributed throughout the year (1971, Mich. Dept. Agr.).

A total of 12 species of trees were observed in the study area whose 1974, 1975, and 1976 measurements were at least the adopted minimum of 5 cm (2 in.) DBH (diameter at breast height, measured at 137 cm = 4 1/2 ft. above ground level). In the winter of 1977 *Amelanchier* sp. with a 5 cm (2 in.) DBH was added. The 13 tree species listed in Table 2 except for large-toothed aspen are also represented by individuals in the pool of those with stems less than 5 cm (2 in.) DBH, i.e., the pool of younger trees from which tally trees are recruited. A species potentially new to the list, *Pinus strobus,* exists but its size is less than the minimal 5 cm (2 in.) DBH adopted for inclusion. Shrub species noted were *Lonicera canadensis* and *Viburnum acerifolium.* Herb stratum and ground cover species include *Adiantum pedatum, Aralia nudicaulis, Clintonia borealis, Galium triflorum, Gaultheria procumbens, Lycopodium clavatum, L. lucidulum, L. obscurum, Maianthemum canadense, Medeola virginiana, Mitchella repens, Monotropa hypopithys, Pyrola elliptica, Pteridium aquilinum, Smilacina racemosa, Streptopus roseus, Trientalis borealis, Trillium grandiflorum,* and *Viola* spp.

Tree DBH measurements were made with a Keuffel and Esser 24" model wooden tree caliper. Such devices owing to their ease of use and rapid computation are frequently employed in lieu of tapes for computing DBH measurements. With the student hands available for the task, the opportunity was taken to obtain a comparison of DBH measurements based on our standard tree calipers with that of tapes. Diameters based on tape measurements of trees whose boles have a cross-sectional shape other than circular might appear more accurate for ascertaining average diameters than would be obtained with tree calipers. Trees in one-fourth of the study area, i.e., rows A through E and columns 1 through 5 were measured both by caliper and by tape. The comparative results are presented in Table 1. The variation in DBH

TABLE 1. Comparison of DBH measurements (in.) using tree calipers and tapes. * Numbers in parentheses = total number trees of that species in all 100 plots. ** Comparisons based on a tree by tree basis.

	Populus grandidentata		Acer saccharum		Acer rubrum	
Total no. trees in 25 plots whose DBH was measured by caliper and tape	101 (441)*		59 (306)		149 (295)	
	Tape	Caliper	Tape	Caliper	Tape	Caliper
Smallest tree	5.8	5.5	2.0	2.0	2.0	2.1
Largest tree	17.0	17.3	7.5	7.3	13.8	14.1
Mean tree size	11.4	11.3	3.4	3.4	5.6	5.5
Mode (nearest 1 inch category)	11	11	2	2	4	4
Median	12.3	11.6	3.1	3.1	5.0	5.0
Greatest difference between tree caliper and tape measurements**	-1.2		+ & - 0.5		-1.6	
No. trees with identical tape and caliper measurements	15		17		25	
No. trees with caliper measurements higher than those of tape	30		21		43	
No. trees with caliper measurements lower than those of tape	56		21		81	
Average caliper error/tree	-0.1		0		-0.1	

when measured both ways is no more than 2.5 mm (0.1 in.) per tree. This holds true for trees with relatively large DBH mean diameters such as 27.2 cm (10.7 in.) for large-toothed aspen as well as for *Acer saccharum* (sugar maple) whose smaller mean DBH was 8.9 cm (3.5 in). However, a discrepancy in DBH of one inch or more was noted in nine instances out of a total of 309 trees measured by both methods.

In Table 2 is listed the total number of trees by species for the years 1975 and 1976. The 1975 data show that almost 40% of the trees in the study area are large-toothed aspen. The next three most abundant species, *Acer saccharum, Acer rubrum* (red maple), and *Fagus grandifolia* (American beech), represent typical successors to large-toothed aspen in similar sites at these latitudes. The approximately 60 years elapsed since the forest was last cut are sufficient to show a trend toward development of an *Acer-Fagus* forest, according to the classification scheme of Benninghoff & Cramer (1963). Such designations refer to good-site stands that are developing a mesophytic community characteristic of the northern hardwoods regional climax.

The 1976 data shown in Table 2 give a preliminary notion of changes in forest composition both in terms of total number of trees as well as changes in total number by species. The total number of trees for 1976 is essentially the same as for 1975. In future years it will be interesting to note changes in the total number of trees and in their size-class distributions in this one-hectare forest plot. It is anticipated that the total number of trees will be less but that the average DBH will increase. (In at least 30 instances for *Acer* spp. four to nine sapling trees occur in rather tight clusters—these likely resulting from adventitious sprouts of parent trees cut years ago. We already can observe evidence of some reduction in the number of stems per cluster owing to death by natural factors.)

TABLE 2. Relative abundance of tree species.

YEAR	Populus grandidentata	Acer saccharum	Acer rubrum	Fagus grandifolia	Betula papyrifera	Betula alleghaniensis	Tilia americana	Acer pensylvanicum	Ostrya virginiana	Quercus borealis	Prunus serotina	Fraxinus americana	Amelanchier sp.	TOTAL
1975	452	296	300	61	24	12	9	7	6	3	3	2	2	1177
1976	439	311	299	62	23	12	10	8	7	3	3	4	2	1183
New Trees		14	6	5			1	1	1			2		30
Dead Trees	13	3	7		1									24
% Change/Species	−3	+4	−.3	+8	−4		+11	+14	+17			+100		+0.5
1977	434	312	294	65	21	12	10	8	7	3	3	4	6	1179
New Trees		4		3									4	11
Dead Trees	5	3	5		2									15
% Change/Species	−1	+.3	−2	+5	−9								+200	−0.3

The number of new trees added to the study area each year, i.e., those which achieve at least 5 cm (2 in.) DBH and the number of trees that die during the year, i.e., recruitment and mortality, provide an indication of the rate of change from one forest type into another. It is anticipated that most available niches in the forest canopy will be filled by dominant or co-dominant species but not necessarily in proportion to their current relative abundance. The 1975 count for large-toothed aspen, 454 trees, in time will likely decline to near zero. The smallest large-toothed aspen known in the study area is 12.4 cm (4.9 in.) DBH. Most of the 13 large-toothed aspen trees lost during 1975 probably fell during a severe winter storm on or about November 10, according to a local resident, Bill Foster (pers. comm.). Graham (1963) discussed a number of fungous infections known for large-toothed aspen. These trees may have already been weakened by infection.

The percentage changes noted in Table 2 represent the differences by species of the number of new trees added compared to the number that died during that year. These percentages provide some indication of the relative ability of each species to withstand changing conditions in a rapidly maturing aspen forest.

In Table 3 are shown size-class tree caliper data obtained in January 1976. The species with the largest mean DBH are large-toothed aspen and paper birch, Both species are early invaders following logging operations. Most species with smaller DBH means will probably remain constituents of the mature northern hardwoods-hemlock-white pine forest. The mean DBH for all species is expected to increase for the next several years. Ultimately, one might anticipate a situation in which average tree size will equilibrate as will the relative number of trees of each species.

This work represents a base-line study which can be used to make actual measurements of the details of the process of plant succession (as far as trees are concerned) in one of our well known forest successions, and with three years of measurements it has been possible to show the actual recruitment of "climax" tree species and mortality of the aspen from the earlier successional stage.

A set of 100 maps to trees in this forestry plot which provided the basis for this study will be deposited at the University of Michigan Biological Station. Although it will be many years before this study is completed, the data presented herein together with the set of maps each representing a 100 meter^2 quadrat will be useful for student exercises in the computation of actual and relative density, dominance, and frequency. The data will also be useful for checking relative accuracy of sampling techniques, at least in this forest plot, of the point quarter method, line intercept, and random pairs.

I would like to express appreciation for assistance from Dominic Morinelli, W. B. McInvaille, Jr., Frank Martin, Mayo Derouchie, the Cranbrook and Kingswood students, and the staff of the University of Michigan Biological Station. I am especially indebted to W. S. Benninghoff for advice and assistance.

TABLE 3. Tree DBH size class data for January 1976.

DBH in inches	Populus grandidentata	Acer saccharum	Acer rubrum	Fagus grandifolia	Betula papyrifera	Betula alleghaniensis	Tilia americana	Acer pensylvanicum	Ostrya virginiana	Quercus borealis	Prunus serotina	Fraxinus americana	Amelanchier sp.	TOTAL
2		118	41	30	1	3	1	3	4	1	2	3	1	208
3		67	51	13		4	1	2			1		1	140
4	1	60	58	11	4	2	1	2	1					140
5	5	30	40	2	3	1	2	1	1					85
6	24	13	37	3	2		2			1				82
7	36	11	35		2		1							85
8	34	3	18		3	1	1		1					61
9	45	5	7		3	1				1				62
10	62	2	6		2									72
11	56	1	2		2		1							62
12	60		1	2	1									64
13	41		2	1								1		45
14	39	1	1											41
15	21													21
16	8													8
17	5													5
18	1													1
19														0
20														0
21	1													1
Total	439	311	299	62	23	12	10	8	7	3	3	4	2	1183
Mean	10.7	3.5	4.9	3.4	7.1	4.0	4.7	3.3	3.6	5.7	2.3	4.8	2.5	6.6
Mode	10	2	4	2	4	3	5	2	2	1	2	2	2.5	2
Median	11	3	4	3	7	3	5.5	3	3	6	2.5	2	2.5	6

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CONTENTS

The Status of Certain Hawkweeds (Hieracium subgenus Pilosella) in Michigan
Edward G. Voss & Mark W. Böhlke 35

Current Status of the Genus Hackelia (Boraginaceae) in Wisconsin
Johnnie L. Gentry, Jr. 48

Reviews 48

The Diatoms of Douglas Lake – a Preliminary List
N. A. Andresen & E. F. Stoermer 49

The Diatom Flora of Tiplady Bog, Michigan
Kyle D. Hoagland & Forrest M. Begres 55

New or Noteworthy Taxa for Central Wisconsin in the Flora of the "Whiting Triangle"
Robert W. Freckmann 65

Tree Populations of a Mature Aspen Forest in Cheboygan County, Michigan
James R. Wells 73

On the cover: Morchella esculenta, *Morel,*
at George Reserve, near Pinckney, Michigan,
May 13, 1933; photo by the late E. B. Mains

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A SCANNING ELECTRON MICROSCOPIC STUDY OF THE TRICHOMES IN BRASENIA SCHREBERI

Kenneth D. Laser

Department of Biology
State University of New York at Stony Brook,
Stony Brook, 11794

The genera of the Cabombaceae, *Brasenia* and *Cabomba*., have similar trichome morphology (Kristen, 1974). Both have secretory trichomes which produce a mucilage on the surface of submerged organs but in greater abundance on younger, developing leaves, petioles, and stems of *Brasenia* (Schrenk, 1888). Trichomes of *Brasenia* have been classified into a multiseriate secretory type and a less abundant uniseriate non-secretory type (Solereder, 1908; Metcalfe & Chalk, 1950; Uphof, 1962). The secretory trichomes were termed "colleters" by Hanstein (1868). Fahn (1974) has regarded similar trichomes as "mucilage secreting glands." Schrenk (1888) has provided an excellent light microscopic review in drawings on the development of the secretory trichomes of *Brasenia peltata* Pursh.

Early investigators of *Brasenia* (Schrenk, 1888; Keller, 1893; Chrysler, 1938) reported the source of mucilage as numerous secretory trichomes on the lower leaf surface. The secretory trichomes of the leaf were described as branched or unbranched and fewer and less active on the petiole and stem. The mucilage of *Brasenia* was described as slime by Schrenk (1888); he regarded the slime necessary for the protection of younger plant parts from herbivorous aquatic animals and from being covered by algae. A similar type of mucilage has been regarded by Schnepf (1969) as mainly a polysaccharide with peptide linkages. Kaul (1976) noted that mucilage adds greatly to the strength of the organs.

In this study the scanning electron microscope was used to elucidate the development and structure of the trichomes and adjacent epidermal cells on submerged plant parts. Routine histochemistry and light microscopic examination of the mucilage were used to verify its chemical composition and the presence of the bacteria and fungi described in studies by Schrenk (1888) and Keller (1893). Numerous filamentous blue-green algae, ciliated protozoans, and diatoms were observed in abundance in the mucilage of the developing shoots verifying Schrenk's (1888) and Uphof's (1962) observations of micro-flora and fauna. The varied sources of mucilage (glycoprotein) on aquatic vascular plants and their role in their environment is now of considerable research interest. This study was undertaken to provide additional information regarding the type, distribution, and development of trichomes on the leaves, petioles and stems of *Brasenia schreberi* using SEM methods.

Specimens of *Brasenia schreberi* were collected from Thompson Lake in Mecosta County, Michigan. The specimens were prepared for SEM observation by fixing segments of the leaf, petiole, and stem in 3% glutaraldehyde in 0.5 M phosphate buffer, pH 7.2, at 4°C for 6 hrs and then post-fixed with OsO_4 vapors generated from a 1% solution of

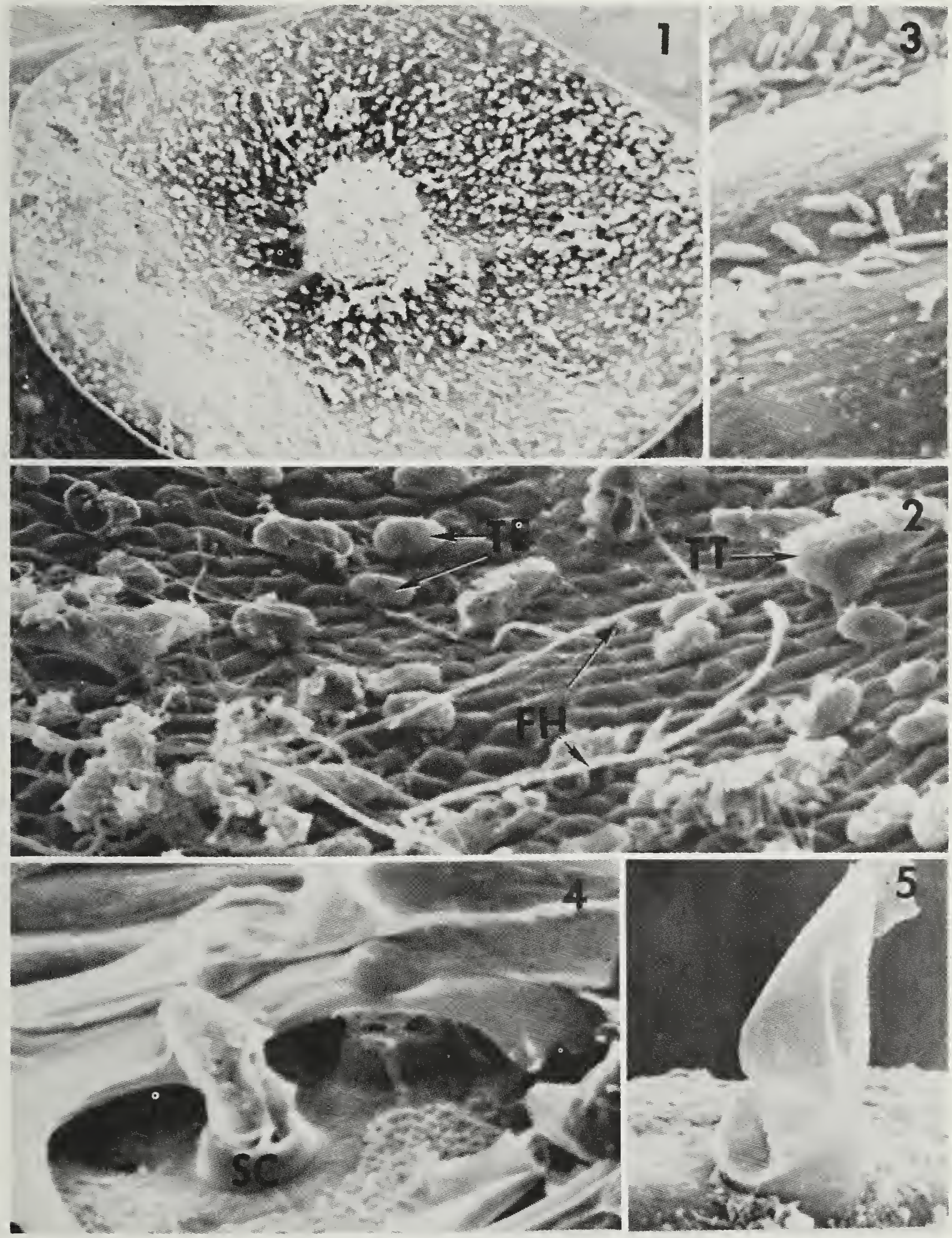
OsO_4 for 2 hrs. at room temperature. A graded alcohol-acetone dehydration sequence was used to bring the specimens to drying in 100% acetone followed by 100% amyl acetate prior to critical point drying with CO_2. The specimens were mounted on aluminum stubs with silver conducting paint and coated with carbon followed by platinum. Specimens were examined in an ETEC autoscan scanning electron microscope at an accelerating voltage of 15 KeV.

Histochemical localization of mucilage (glycoprotein) produced by trichomes was identified by the periodic acid-Schiff's reaction (PAS) for carbohydrates and the brom cresol blue reaction for total proteins (Jensen, 1962). The mucilage in this study was identified as a glycoprotein, using the methods of Gottschalk (1972).

The aquatic herb, *Brasenia schreberi* Gmel., commonly known as watershield, water target, purple bonnet or purple wen-Dock, is characterized by its floating, long-petioled, peltate leaves with numerous trichomes on the lower surface. Stomata are present only on the upper cuticularized leaf surface which is devoid of trichomes. The trichomes of the abaxial surface of the floating leaves are well developed and secrete an abundance of mucilage. The epidermal cells developing into trichomes are circular and smaller than the surrounding bulging epidermal cells. The uniseriate non-secretory trichomes have a broad circular basal cell with an elongate extension which projects above the epidermis. The secretory trichomes vary in size and shape on the leaf, petiole, and stem and may be club-shaped, globular, or sickle-like, or without a pedicel or stalk. They have from one to three pedicel cells and a larger apical cell. The mature trichome is surrounded by an inflated membranous sac which bursts, releasing mucilage and exposing the trichome which is eventually shed from the surface.

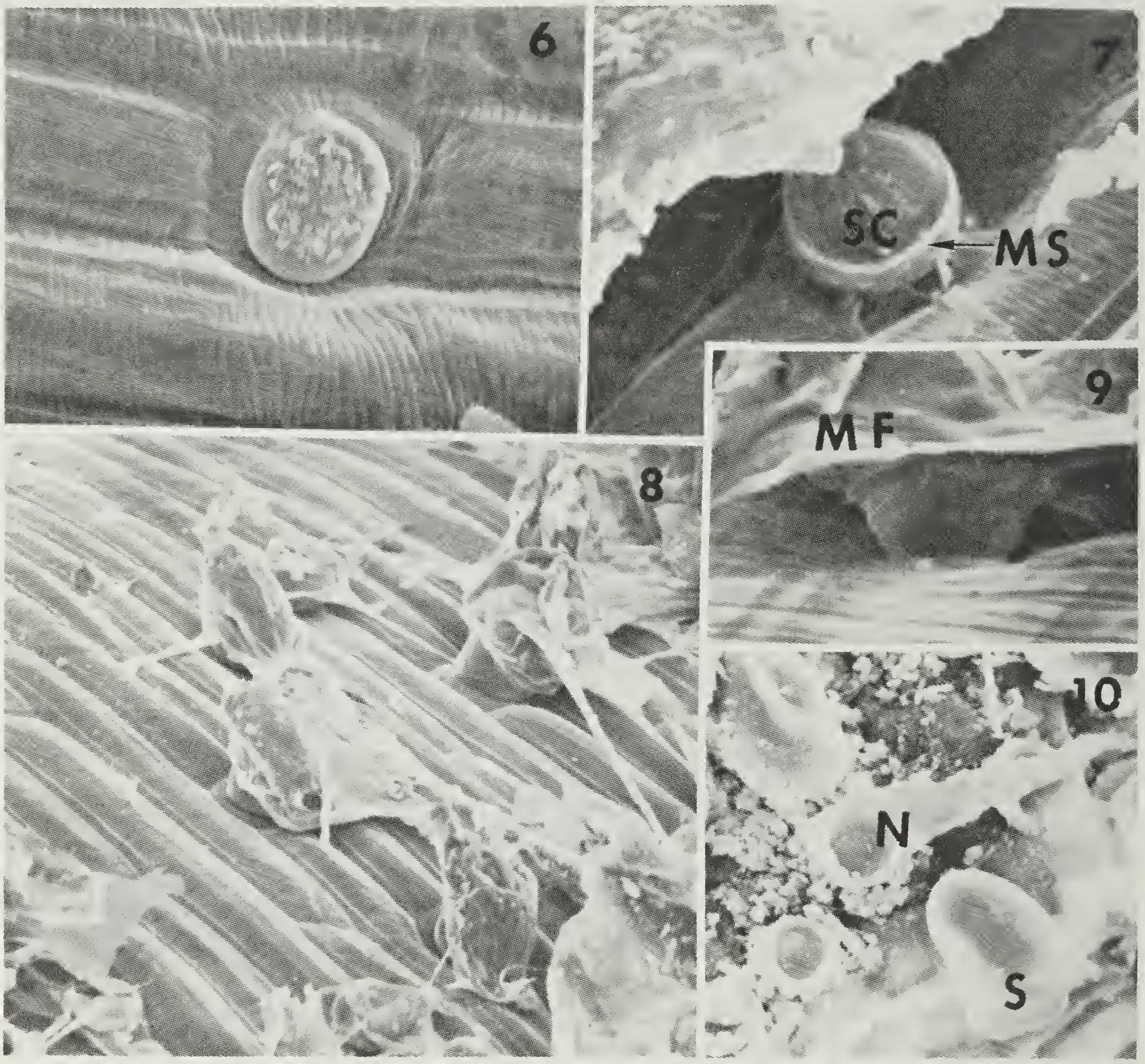
Trichomes at various stages of development are located on the submerged leaf, petiole, and stem. Figure 1 shows a typical distribution pattern of secretory trichomes on the abaxial leaf surface in relation to those on the portion of petiole. A higher magnification of the same leaf surface (Fig. 2) shows two types of secretory trichomes with adjacent epidermal cells that bulge and appear wavy. The usual type of secretory trichome is rounded and egg-shaped, while the T-shaped type with a stalk protruding from the surface is less abundant. A gram-positive *Bacillus* (Fig. 3) was found on the submerged plant surface together with some unidentified fungal hyphae (Fig. 2). Schrenk (1888) and Keller (1893) also identified *Bacillus* bacteria in mucilage of *Brasenia peltata.* A later stage of the developing secretory trichome is shown in Fig. 4. The trichome protruding from a circular eipdermal cell has a stalk cell bearing an attached collapsing membranous sac. A filmy mucilage (glycoprotein) covers the adjacent trichomes. The non-secretory type of trichome (Fig. 5) develops an elongate membranous extension of a portion of the membrane surrounding the emerging trichome cell. This trichome does not continue to develop, except for a membranous extension.

Specimens of petioles from younger plants clearly illustrate the developmental stages of trichomes from an early (Fig. 6-7) to a later secretory stage (Fig. 8). The earliest stages of secretory trichome development (Fig. 6) show a slight bulging of the trichome which is subepidermal in origin through the already existing ellipsoid epidermal cell. The epidermal cell bearing this trichome is smaller than the adjacent cells. A slightly more developed

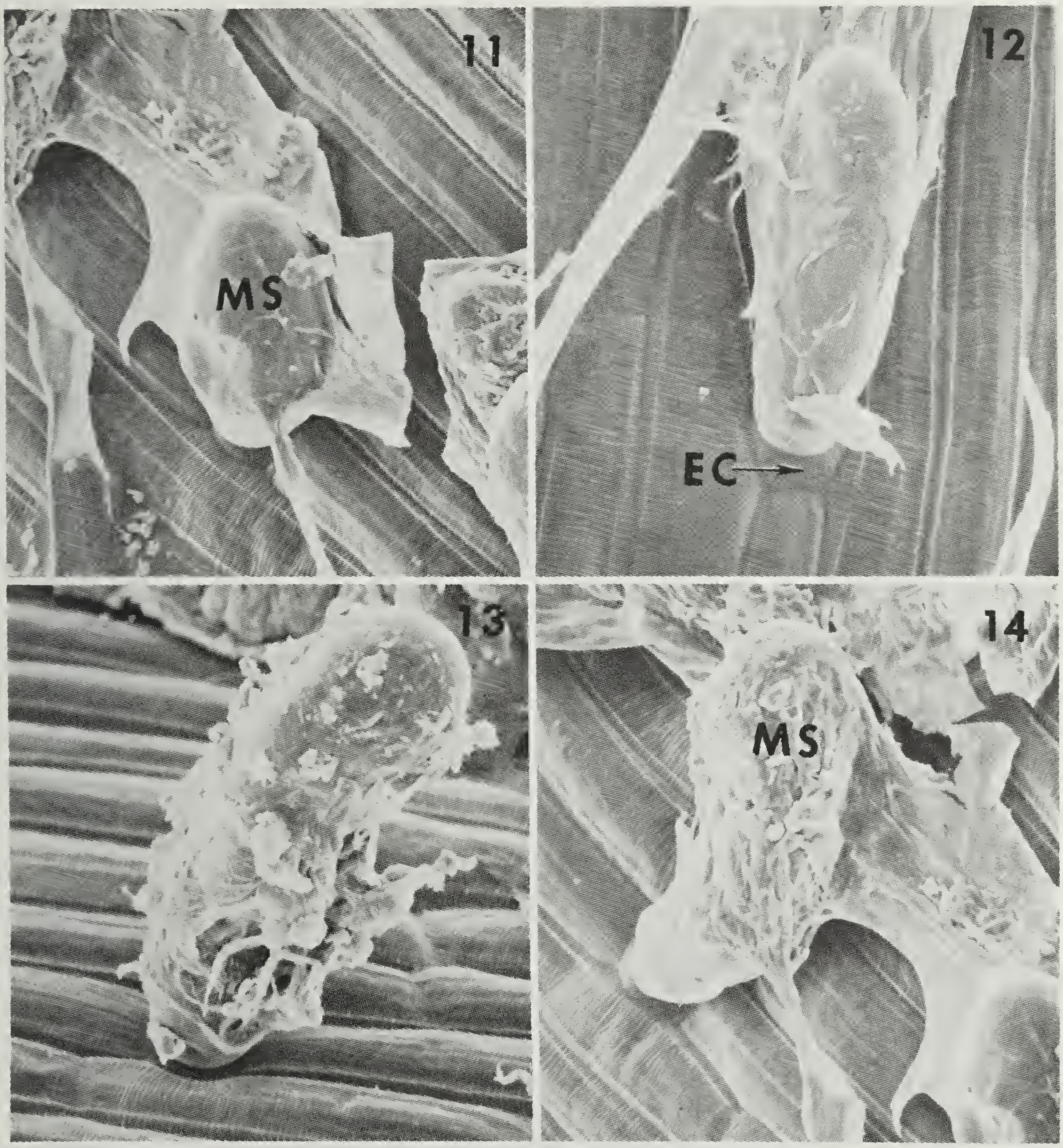


Figs. 1-5. 1. Entire peltate leaf of Brasenia schreberi showing abaxial submerged surface. ×72. 2. Abaxial leaf surface showing two types of secretory trichomes: egg-shaped (TE) and T-shaped (TT) (arrows). Note fungal hyphae (FH). ×560. 3. Bacillus type of bacterium on lower leaf surface. ×11,900. 4. A secretory trichome of the submerged leaf with attached stalk cell (SC). Note film of mucilage on adjacent trichomes. ×900. 5. A non-secretory (clothing) trichome on the lower leaf surface. ×3520.

trichome (Fig. 7) shows the membranous sac as it begins to develop around the protruding apical cell of the three-celled trichome. The relationship and distribution of secretory trichomes to other epidermal cells (Fig. 8) are shown with a filmy layer of mucilage still attached between trichomes. The basal (stalk) cell can be seen (Fig. 9) as it projects above the trichome epidermal cell. A less abundant non-secretory trichome on the petiole, often noted next to a secretory trichome (Fig. 10), appears like the non-secretory type located on the submerged leaf (Fig. 5). In one of the earlier stages, the developing petiole trichome (Fig. 11) emerges from the surface followed by the inflation of the apical cell and surrounding membranous sac. Strands of mucilage connecting this trichome with adjacent trichomes are common. As the filmy

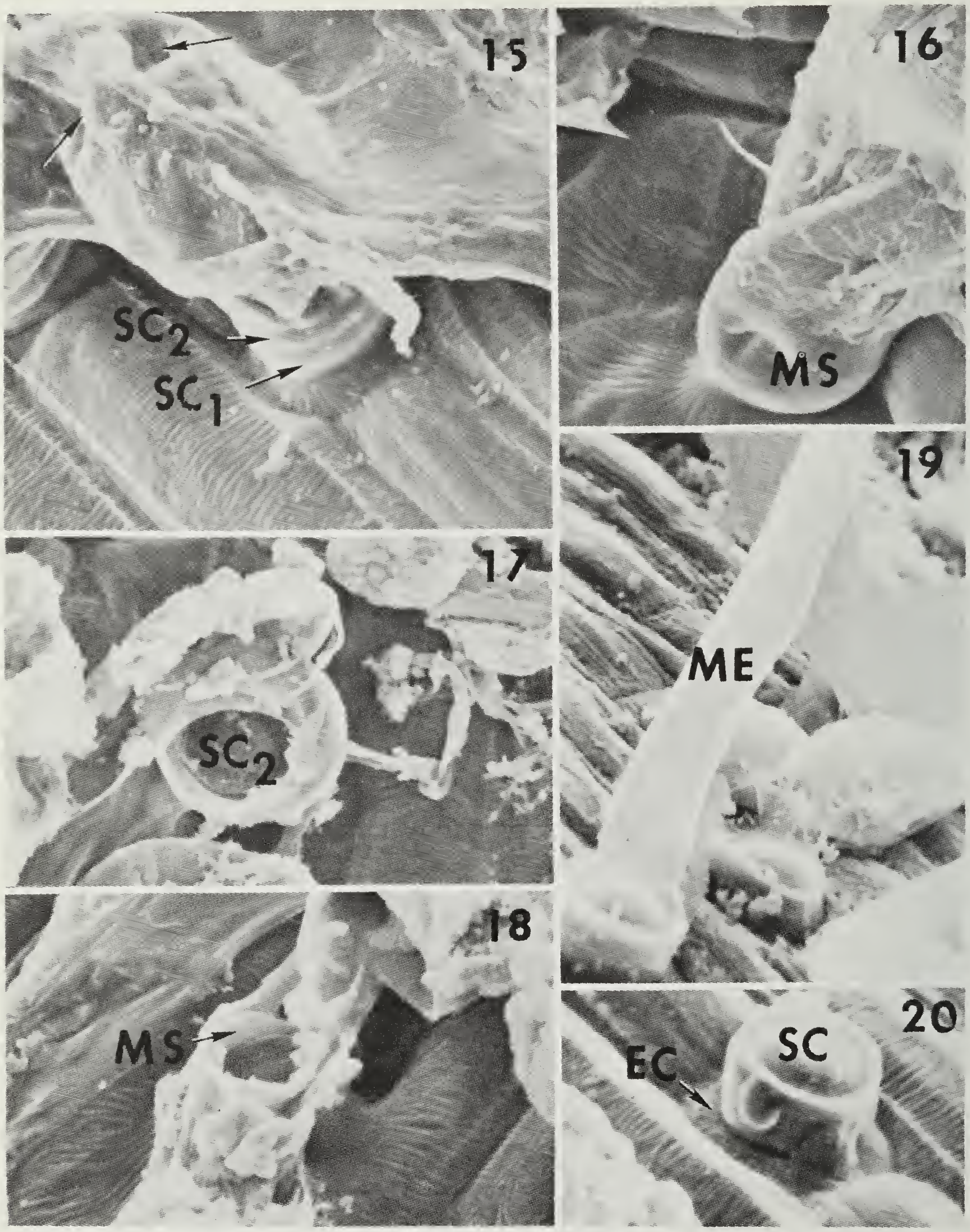


Figs. 6-10. Various developmental stages of petiole trichomes. 6. An emerging secretory trichome. Note the adjacent wavy epidermal cell surface. ×1200. 7. An emerging secretory trichome with membranous sac (MS) and enlarged stalk cell (SC). ×1400. 8. A later stage of the secretory trichome with attached filmy mucilage. ×560. 9. The basal stalk cell of an emerging secretory trichome. ×1120. Note attached membranous film (MF). 10. An inflated secretory trichome (S) adjacent to a non-secretory trichome (N). Note the membrane extension of the latter. ×560.



Figs. 11-14. Later stage in the development of secretory trichomes on the submerged petiole. 11. ×880. Fig. 12-14. ×960. Note the partly exposed ellipsoid epidermal cell (EC) of the secretory trichome (Fig. 12) and the membranous sac (MS) surrounding the secretory trichome (Fig. 11-14).

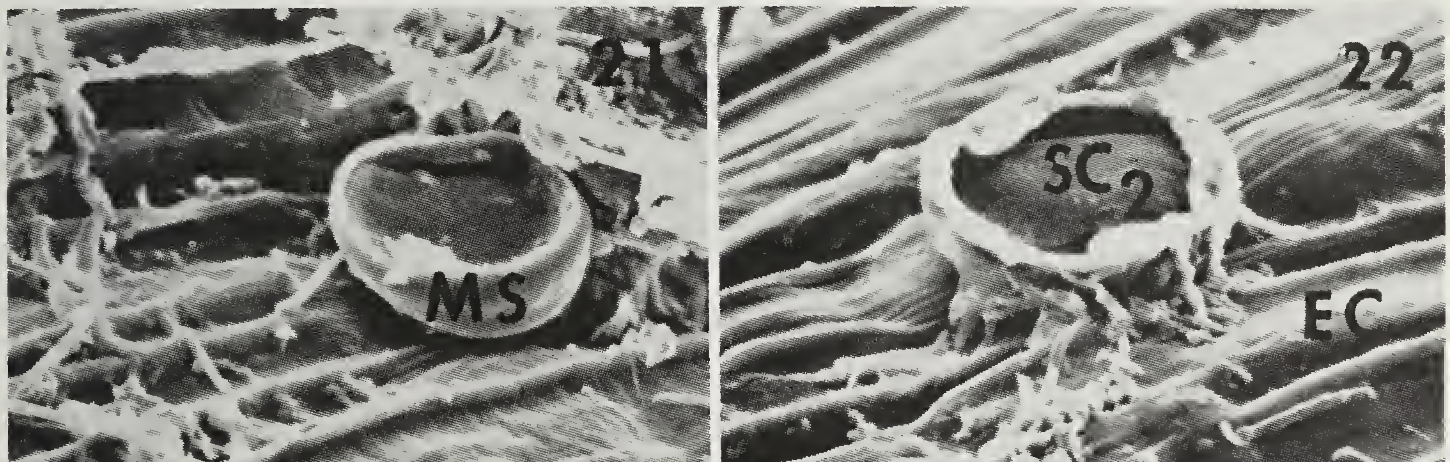
membranous sac continues to fill with mucilage it elongates (Fig. 12) until the trichomes appear two to three times as long as wide (Fig. 13). The film of mucilage which covers the entire submerged plant at this stage of development continues to adhere closely to the trichomes (Fig. 14) but is free from the epidermal surface. The apical cell region of the trichome (Fig. 15-arrows) is somewhat collapsed, probably as a result of bursting, releasing its mucilage contents into the membranous sac surrounding the trichome and externally. This same trichome has two stalk cells apparent above the epidermis. Further degeneration of the secretory trichome (Fig. 16) is evident by the major



Figs. 15-20. 15. A secretory trichome in which the apical cell has collapsed (arrows). ×1040. Note the two stalk cells (SC_1, SC_2), 16. A more advanced stage of secretory trichome degeneration. Note that the membranous sac (MS) is almost totally deflated. ×960. 17. The membranous sac of a secretory trichome has burst exposing the uppermost stalk cell (SC_2). ×960. 19. A non-secretory type trichome with a membrane extension (ME) at a late stage of development. ×1200. 20. The exposed stalk cell (SC) of a non-secretory trichome. ×1400. Note the membranous fragment has almost deteriorated. Note also the circular epidermal cell (EC) of the emerged non-secretory trichome.

depression inside of the membrane covering the trichome. The final stages of secretory trichome degeneration on the petiole take place when the opening in the membranous sac (Fig. 17) becomes quite large, releasing the mucilaginous contents and exposing the surface of the uppermost stalk cell. Almost all of the membranous sac is shed (Fig. 18), with remnants only in the area of the stalk cell. The non-secretory type of trichome (Fig. 19) shows a similar stage of development similar to that of the secretory trichome. Here, a long extension of a portion of the surface membrane remains attached to the most distal stalk cell.

The submerged stem of *Brasenia* has fewer secretory trichomes during the same developmental stages of the submerged leaf and petiole. Early and later development of these trichomes indicates a slight enlargement of the membranous sac above the stalk followed by a collapse of the sac without bursting (Fig. 21). The membranous extension of non-secretory trichomes may



Figs. 21-24. Developmental stages of secretory trichomes of the stem. ×1400. 21. Early developing trichome with a collapsed membranous sac (MS). 22. Trichome whose membrane has been nearly obliterated exposing the uppermost stalk cell (SC_2). Note the adjacent epidermal cells (EC) are wavy with ridges widely spaced. 23. These trichomes have lost their membranous sac exposing the uppermost slightly porous stalk cell. 24. A receded stalk cell (SCr).

degenerate or break off in older submerged stems (Fig. 20). Often the slightly enlarged membranous sac will inflate, then burst (Fig. 22), and will finally degenerate completely (Fig. 23). The surface of an exposed stalk cell which has receded is shown in Figure 24. This might indicate a collapsing of the stalk or wearing away of the uppermost stalk cell. In the submerged stem the epidermal cells adjacent to the trichome are not as bulged or uniform in their appearance as observed on the leaf and petiole.

The scanning electron microscope, unlike the compound light microscope used by earlier investigators (Schrenk, 1888; Keller, 1893) and the transmission electron microscope used recently (Kristen, 1974), has elucidated the morphology, development, and distribution of the mucilage secreting trichomes of leaves of *Brasenia schreberi.* The earlier studies showed that the more abundant trichomes are secretory while the less abundant ones are non-secretory (clothing), and also demonstrated that the secretory trichomes produce a mucilage or glycoprotein. The development and distribution of the secretory trichomes is shown to be quite similar on the submerged portion of the leaf and petiole (Fig. 2, 8, 12) and less distinct on the stem (Fig. 21).

Early investigators (Schrenk, 1888; Keller, 1893) have shown the development of the secretory trichome on the leaf; however, the SEM in this study shows more clearly the development of the secretory trichome on the leaf and petiole during the enlargement of the membranous sac surrounding the apical cell of the trichome and its ultimate collapse releasing mucilage to the plant surface. Also it is of special significance that the epidermal cell from which both types of trichomes of the leaf and petiole emerge is circular to ellipsoid (Figs. 4, 12, 20), while the epidermal cell of the stem trichomes (Fig. 23) appears non-distinct with a circular ridge.

The presence, distribution, and morphology of the relative few trichomes on the stem compared with the abundant supply on the leaf and petiole were explored extensively in this investigation. As noted in Figures 21-22 the membranous sac undergoes initial development, presumably with a stalk cell. Once the sac ruptures and is completely obliterated (Fig. 23) its recession back under the circular ridge, appearing sunken, is very often evident (Fig. 24). The circular ridge at the base of the trichome is always present on multiseriate trichomes of the stem. The special significance of the circular ridges and their development on the stem and not on the leaf or petiole may be worth exploring in future studies.

SUMMARY

The ultrastructure of the trichomes of the submerged leaf, petiole, and stem of watershield (*Brasenia schreberi*), collected in Mecosta County, Michigan, was investigated using scanning electron microscopy. The submerged surfaces of these plant organs are covered with a gelatinous mucilage (glycoprotein). Two types of trichomes were observed on the leaf and petiole, a secretory and a less abundant non-secretory type. Trichomes resembling the secretory type were observed on the stem. The distribution and development of both types of trichomes in relation to adjacent epidermal cells are elucidated. This study clearly demonstrates the presence and external development of secretory trichomes on leaves, petioles, and stems of this aquatic angiosperm. The development of the trichomes and their glycoprotein secretion illustrates only one more example of the ubiquitous source and nature of this mucilage in aquatic environments.

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VEGETATIONAL PATTERNS ON THE TITTABAWASSEE FLOODPLAIN AT THE GOETZ GROVE NATURE CENTER, SAGINAW, MICHIGAN

Richard H. Wheeler and Ronald O. Kapp

Department of Biology,
Alma College, Alma, Michigan, 48801

For several years researchers at Alma College have studied vegetational history, land use patterns, and forest resources in the Pine River watershed; the easternmost boundary of this watershed joins the Tittabawassee River drainage basin. In an effort to broaden the base of research on the ecosystems of the floodplain of central Michigan streams, the authors studied some of the factors related to plant distribution patterns at the Goetz Grove Nature Center located on the Tittabawassee River floodplain at Saginaw. This provided an opportunity for comparison with unpublished research on floodplain forests of the Pine River (Povich, 1975; Budge, 1974; Edgar & Wilson, 1974; Navarre, 1976). Two factors were analyzed to determine their significance in the distribution of floodplain species: exposure to sunlight (dominance of species in open or closed canopy situations) and tolerance to moisture (restricted to or abundant in areas of low elevation and high moisture, or found only at higher elevations).

The study area is located within the Tittabawassee floodplain about one-fourth mile upstream from the point at which the confluence of the Tittabawassee, Shiawassee and Cass Rivers forms the Saginaw River (Fig. 1). The tract lies north of the river partly in the NE 1/4 and partly in the SE 1/4, Sec. 3, T11N, R4E, Saginaw County. This area has been designated by the Saginaw Parks Department as the Goetz Grove Nature Center. The entire nature center covers 76 acres (30.4 ha); only the southernmost 19 acres (7.6 ha) which delimit the floodplain area were surveyed for this report.

The topography of the study area is a series of low channels and beach ridges; the study area is more level at the north end (Fig. 2). The elevational extremes are 585.75′ and 580.75′ above mean sea level. Standing water ranged from 2-8″ deep in the low channels during the summer of 1976. The soils of the floodplain are primarily fine alluvial silts and sands of the type mapped as Genessee fine sandy loam on the floodplain of the adjacent Cass River (Deeter & Matthews, 1926). The soils remain perpetually moist except in areas exposed to direct sunlight.

The forests are successional, second-growth stands. The area was probably cleared of original timber in about 1856 (Mills, 1918), and selective cutting has occurred since then. This area has been highly disturbed by man; it is located within the city limits of Saginaw, next to Greenpoint landfill, one-fourth mile

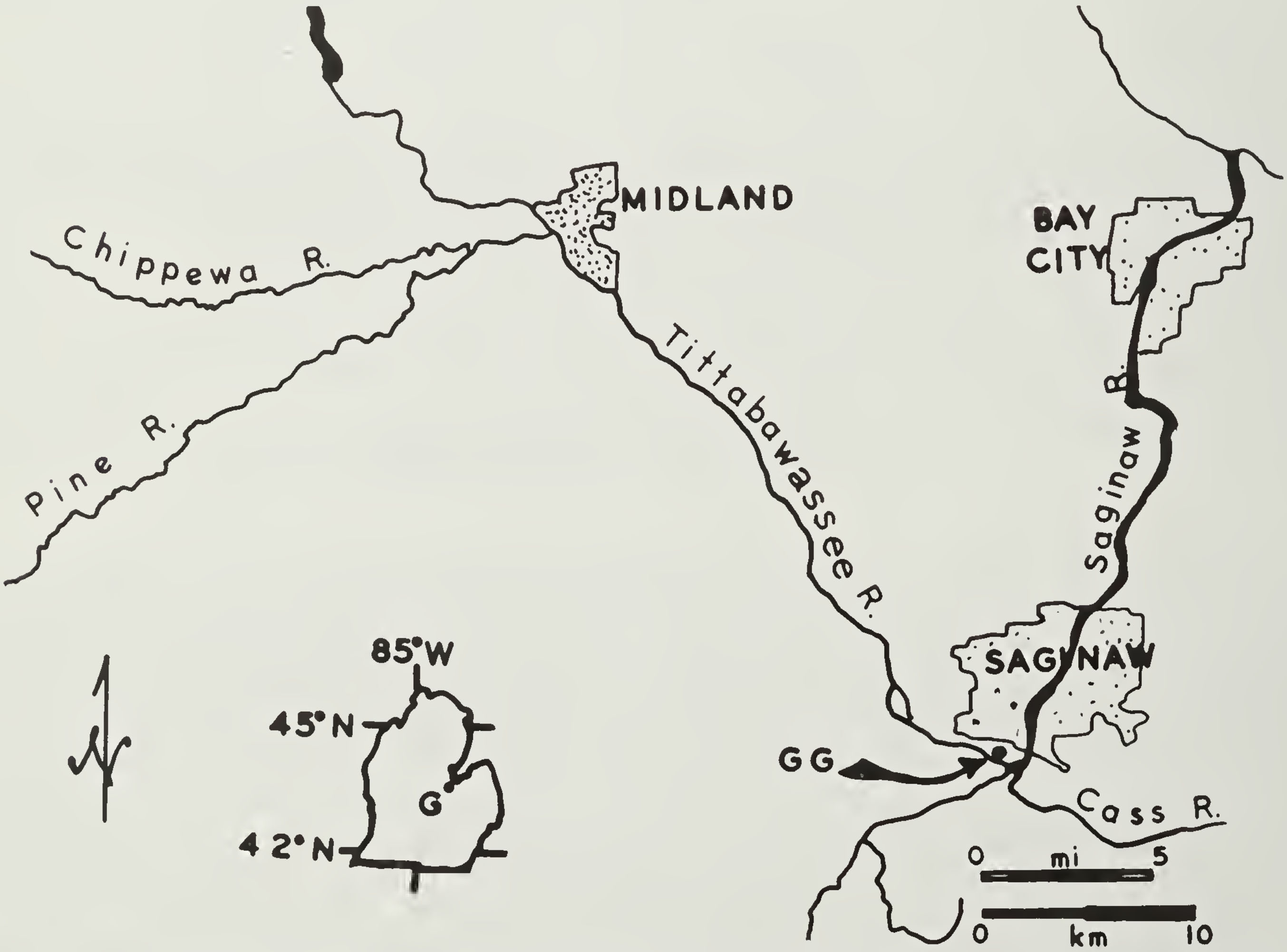

Fig. 1. Map showing the location of Goetz Grove Nature Center, in relation to tributaries of the Tittabawassee and Saginaw Rivers.

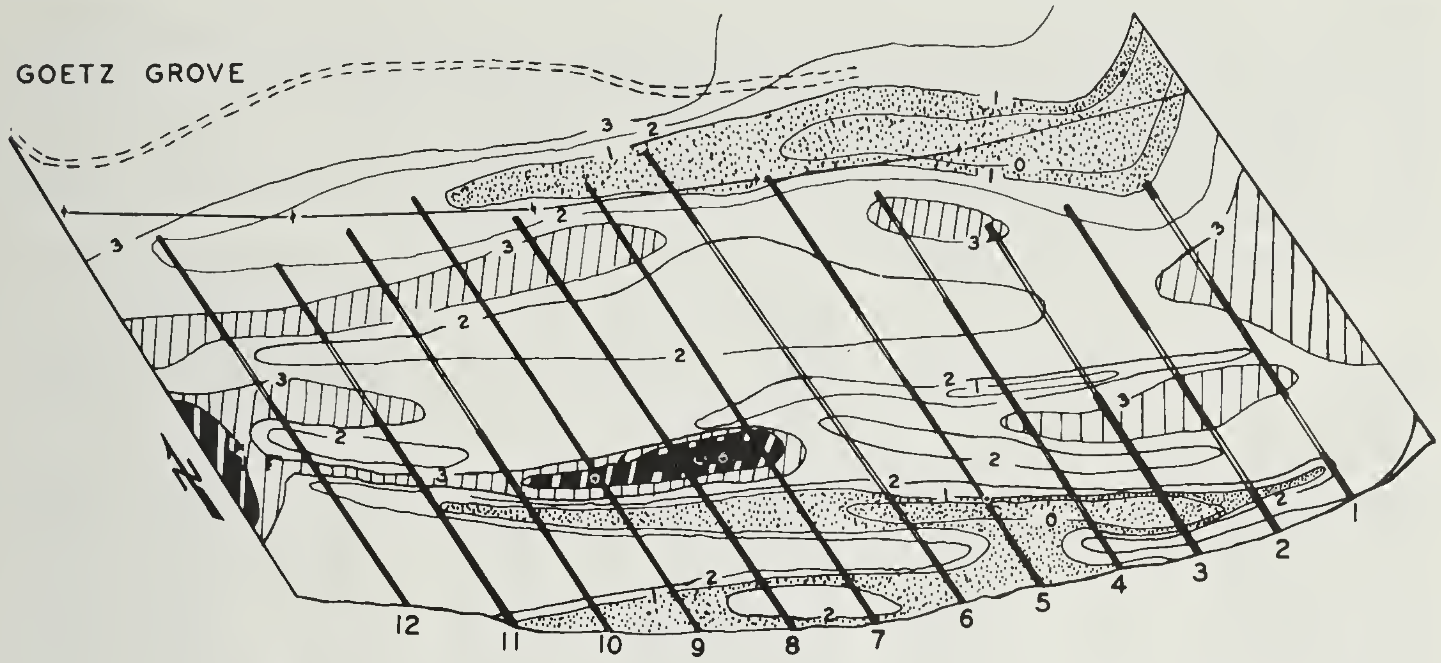

Fig. 2. Topographical contour map of Goetz Grove study tract depicting elevations above the Tittabawassee River (South boundary) and showing locations of the 12 study transects. Where forest canopy was absent or open, the transect line is shown as an open bar sector; closed canopy is shown by the blackened bar; the semiclosed canopy area of transect 5 is cross-hatched.

south of a residential area, and is directly exposed to industrial waste and the water and air pollution from nearby factories. It is currently being developed as a nature center and nature trails are being installed in parts of the study tract.

Field Techniques

All plant species intercepting a series of N-S line transects were recorded on field data sheets. Record was made of the occurrence of each species, including its location and extent of cover along the individual transect lines (Fig. 2). All records of cover are to the nearest foot; cover of less than 6″ was not tallied. All transects started at the southern end of the study area from the northern well-drained portion of the nature center property. At the completion of each transect the accuracy of the measurements were checked, and topography, elevations, canopy closure, community type and patterns of plant distributions were noted. All data were collected between August 24 and September 12, 1976.

Analysis of Data

The *absolute dominance* (AD) of each species was calculated as $\frac{d^x}{L} \times 100$, in which d^x is the distance intercepted by species x and L is the total length of the 12 transects. *Absolute frequency* (AF) for each species was determined as $\frac{n^x}{12} \times 100$, in which n^x is the number of transects in which species x was found.

Relative dominance (RD) was calculated as $\frac{AD^x}{AD^x + y \ldots + n} \times 100 = RD^x$, in which the absolute dominance of species x was divided by the sum of absolute dominances of all species. *Relative frequency* (RF) was determined in the same manner: $\frac{AF^x}{AF^x + y \ldots + n} \times 100 = RF^x$.

An *Importance Value Index* (IVI) was developed as the sum: $RD^x + RF^x = IVI$. This formula for importance value is suggested by Cain & Castro (1959) in instances in which Relative Density is not available.

The species in the stand table (Table 1) are grouped as trees, shrubs, or herbs and are further arranged sequentially according to IVI value; this table also serves as a complete species list.

TABLE 1. Vascular plant species of Goetz Grove Nature Center floodplain showing absolute dominance (Ab. Dom.), relative dominance (Rel. Dom.), relative frequency (Rel. Freq.), and importance value index (I.V.I.). The relative dominance with respect to openness of the forest canopy is provided as well as the statistical probability (P) that the deviation from mean rel. dom. of open and closed canopy is due to chance alone. Nomenclature, in the main, follows Fernald (1950).

Species	Ab. Dom.	Rel. Dom. (%)	Rel. Freq. (%)	IVI	Canopy Character (Rel. Dom. %)		(P)
					Open	Closed	
TREES							
Crataegus spp.	29.9	13.89	3.47	17.36	9.2	43.7	.001
Carya cordiformis	14.42	6.70	3.47	10.17	4.1	16.0	.001
Acer negundo	12.02	5.58	3.47	9.05	2.6	14.1	.001
Ulmus rubra	8.78	4.07	3.47	7.54	2.4	12.9	.001
Juglans nigra	5.27	2.44	2.31	4.75	1.2	10.3	.001
Juglans cinerea	4.9	2.27	1.44	3.71	.07	5.9	.001
Celtis occidentalis	1.78	.82	2.60	3.42	1.7	3.2	.05
Salix cf. nigra	3.15	1.46	1.15	2.67	0	3.3	.001
Ulmus americana	.74	.34	2.02	2.36	0	.96	.01
Sambucus pubens	1.16	.53	1.73	2.26	0	2.1	.001
Carya ovalis	.51	.23	1.44	1.67	1.4	.96	.30
Carya ovata	1.04	.48	1.15	1.63	0	1.9	.001
Populus deltoides	.43	.19	.86	1.05	.3	.03	.10
Acer rubrum	.12	.05	.86	.91	.07	.3	.30
Acer saccharinum	.25	.11	.28	.39	0	.67	.01
Tilia americana	.07	.03	.28	.31	0	0	-
SHRUBS AND VINES							
Vitis spp.	27.64	12.84	3.47	16.31	15.3	29.1	.001
Rhus toxicodendron	8.25	3.83	3.47	7.3	5.6	12.4	.001
Parthenocissus quinquefolia	6.92	3.21	3.47	6.68	3.5	6.2	.01
Cornus stolonifera	.67	.31	2.31	2.62	0	1.2	.001
Ribes sp.	.36	.16	1.44	1.60	0	.46	.05
Rubus occidentalis	.17	.07	.86	.93	1.5	.81	.10
Xanthoxylum americanum	.02	.009	.28	.29	0	.07	.50
HERBS							
Lysimachia nummularia	6.29	21.5	3.47	24.97	23.1	60.8	.001
Aster ontarionis	8.61	4.00	3.47	7.47	4.1	12.5	.001
Tovara virginiana	8.89	4.13	3.18	7.31	.67	13.9	.001
Geum canadense	6.73	3.12	3.47	6.59	2.7	8.2	.001
Glechoma hederacea (Nepeta)	2.84	1.31	2.89	4.2	.45	5.5	.001
Echinocystis lobata	2.55	1.18	2.60	3.78	.22	2.4	.001
Carex sp.	1.33	.61	2.89	3.5	.52	1.9	.01
Thalictrum dasycarpum	.82	.38	2.89	3.27	0	1.2	.001
Rudbeckia laciniata	.09	.50	2.60	3.10	.07	2.6	.001
Oxalis sp.	.68	.31	2.60	2.91	.52	1.3	.10
Lysimachia ciliata	.47	.21	2.60	2.81	.29	.71	.20
Viola nephrophylla	.91	.42	2.31	2.73	0	2.1	.001
Solanum dulcamara	.63	.29	2.31	2.60	.59	.18	.10
Leersia oryzoides	1.82	.84	1.73	2.57	.29	1.7	.01
Impatiens biflora	.37	.14	2.31	2.45	.52	.46	.001
Laportea canadensis	.28	.13	2.02	2.35	.07	.53	.10
Circaea quadrisulcata	.41	.19	1.44	1.69	.14	.75	.05
Solidago gigantea	.45	.20	1.44	1.64	.59	.86	.90
Bidens frondosa	.24	.11	1.44	1.55	.44	.14	.20

TABLE 1. Continued.

Species	Ab. Dom.	Rel. Dom. (%)	Rel. Freq. (%)	IVI	Canopy Character (Rel. Dom. %) Open	Closed	(P)
Alisma subcordatum	.09	.04	1.15	1.19	0	.07	.50
Geum maculatum	.22	.10	.57	.67	0	0	–
Barbarea vulgaris	.14	.06	.57	.63	.52	0	.001
Epilobium adenocaulon	.15	.06	.57	.63	0	0	–
Lythrum salicaria	.11	.05	.57	.62	.52	.25	.20
Nepeta cataria	.08	.03	.57	.60	.14	.07	.90
Plantago major	.03	.01	.57	.58	0	.07	.50
Dioscorea villosa	.02	.009	.57	.63	0	0	–
Oenothera cf. biennis	.07	.03	.28	.31	0	0	–
Daucus carota	.01	.004	.28	.28	0	0	–
Lindernia dubia	.03	.013	.28	.29	.15	0	.10

Data from transects 2, 5, 8, and 11 were used to analyze the relationship of species distribution to topographic variation of the area. Six elevational categories were recognized: 0-1′, 1-2′, 2-3′, 3-4′, 4-5′, and > 5′. The RD for each species was then determined for each elevational category. The significance of species affiliation with specific elevation levels, to be discussed later, were tested by calculating a Chi Square value; for this test mean values (RD) over the entire tract for each species were compared with RD of the species at each elevational level. Graphs were also made for selected species plotting the RD against the elevation to depict elevational affinities (Fig. 4 and 5).

To determine tolerance to sunlight, data from transects 1, 3, 6, 7, 8, and 10 were used as representative of variations in the canopy cover of the overall community. A map showing the general canopy structure was composed from field notes. Determination as to the "openness" of a specific segment of a line was drawn from this map (Fig. 2). The relative dominance of a particular species in the open canopy area was calculated and compared with the RD of that species in the closed canopy situation. Chi Square (x^2) values were then derived to determine if a species' distribution with respect to openness of canopy was random or selective (Table 1); values (P) of .05 and smaller were considered significant, and species with such values were considered to be selective for or against closed canopy.

The Importance Value Indices of species encountered in the study are recorded in Table 1. *Lysimachia nummularia,* an herbaceous creeping vine, had the greatest dominance value in the study area. Other species with the highest IVI values, in order of decreasing dominance, are *Crataegus* spp., *Vitis* spp., *Carya cordiformis, Acer negundo, Ulmus fulva, Aster ontarionis, Tovara virginiana, Rhus toxicodendron,* and *Parthenocissus quinquifolia.*

The data (Table 1) indicate that certain species are affiliated with either the open or the closed canopy areas. Species with a marked affinity for the closed canopy areas are *Lysimachia nummularia, Tovara virginiana, Nepeta (Glechoma) hederacea, Viola nephrophylla, Rudbeckia laciniata, Rhus toxicodendron, Cornus stolonifera,* and *Thalictrum dasycarpum.*

Figure 3 shows the distribution of the floodplain vascular plants with respect to the various elevational levels at the tract. The relative dominance of each species was calculated separately for each elevational category. The significance of these patterns was tested (Chi-square) by determining the

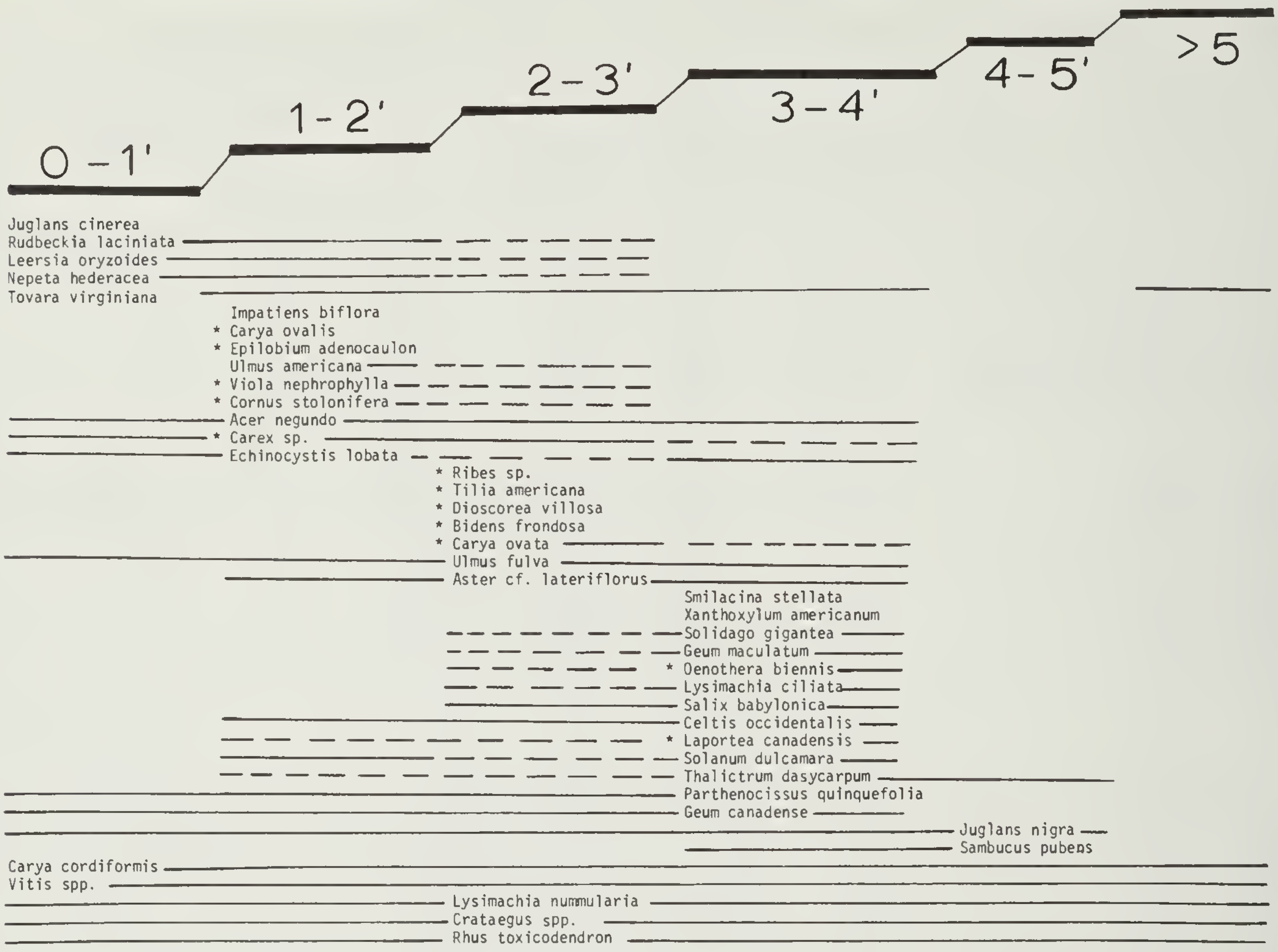
0 – 1'
1 - 2'
2 – 3'
3 – 4'
4 - 5'
>5
Juglans cinerea
Rudbeckia laciniata
Leersia oryzoides
Nepeta hederacea
Tovara virginiana
Impatiens biflora
* Carya ovalis
* Epilobium adenocaulon
Ulmus americana
* Viola nephrophylla
* Cornus stolonifera
Acer negundo
* Carex sp.
Echinocystis lobata
* Ribes sp.
* Tilia americana
* Dioscorea villosa
* Bidens frondosa
* Carya ovata
Ulmus fulva
Aster cf. lateriflorus
Smilacina stellata
Xanthoxylum americanum
Solidago gigantea
Geum maculatum
* Oenothera biennis
Lysimachia ciliata
Salix babylonica
Celtis occidentalis
* Laportea canadensis
Solanum dulcamara
Thalictrum dasycarpum
Parthenocissus quinquefolia
Geum canadense
Juglans nigra
Sambucus pubens
Carya cordiformis
Vitis spp.
Lysimachia nummularia
Crataegus spp.
Rhus toxicodendron

Fig. 3. Diagram showing the elevation at which the common species attained their highest relative dominance (column in which name is listed), consistently high values (solid lines), or were present but not dominant (dashed lines). Table showing relative dominance of each species at the various elevation is available upon request. *(Aster lateriflorus* has been redetermined as *A. ontarionis.)*

probability that the observed dominance was due to chance variations from the average dominance expected if there was no selectivity with respect to elevation; those species marked with an asterisk had probabilities which may indicate no significant elevational affinity.

Species found to be prominent at the low (0-1′) elevation zone were *Juglans cinerea, Rudbeckia laciniata, Leersia oryzoides,* and *Nepeta (Glechoma) hederacea. Impatiens biflora* and *Carya ovalis* were most dominant at the 1-2′ level. *Ribes* spp., *Tilia americana, Dioscorea villosa* were restricted to the 2-3′ level. Prominent at the 3-4′ elevation were *Smilacina stellata, Xanthoxylum americanum, Solidago gigantea, Salix babylonica,* and *Laportea canadenis.* Those dominant at the 4-5′ level were *Juglans nigra* and *Sambucus pubens*; those at the 5′ level were *Tovara virginiana* and *Parthenocissus quinquefolia* (Fig. 3).

Species which initially seem to have indiscriminate distribution patterns with respect to elevation sometimes display a particular elevational correlation. For example, when Relative Dominance is plotted against elevation, *Carya cordiformis* shows a strong affinity for the low elevation level and thus higher moisture availability (Fig. 4). Likewise *Vitis* spp., *Crataegus* spp. and *Rhus toxicodendron* demonstrate an affinity for the 2-3′ level with a lesser tolerance for the drier and wetter areas. While *Lysimachia nummularia* also

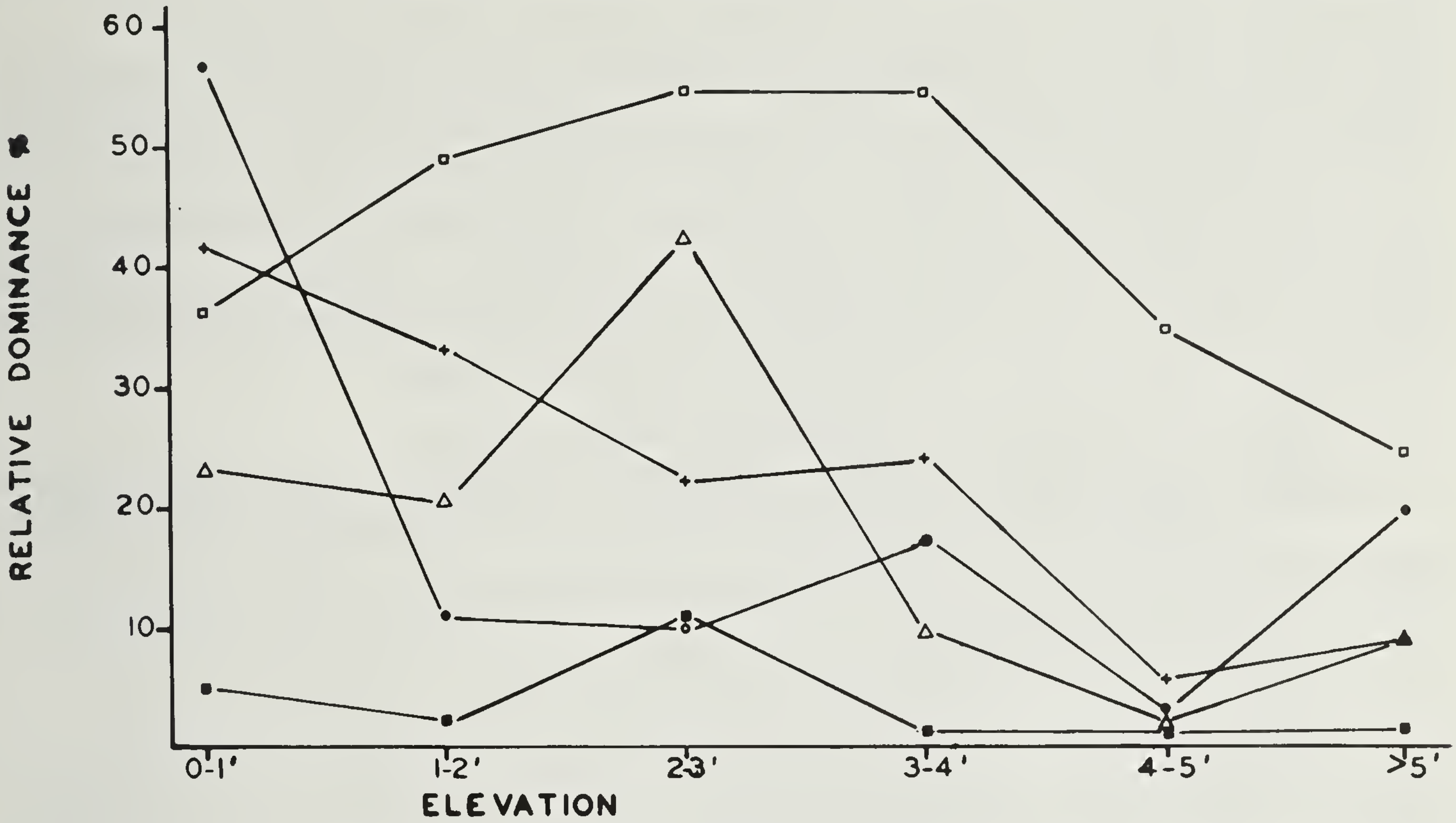

Fig. 4. Relative dominance of five species correlated with elevation of floodplain sites at Goetz Grove Nature Center (*Carya cordiformis*-circle, *Vitis* spp.-cross, *Lysimachia nummularia*-open square, *Crataegus* spp.-triangle, *Rhus toxicodendron*-solid square).

shows an affinity for the intermediate level, its curve is smoother and not as narrowly defined as the previous two species (Fig. 4).

Two species show a bimodal pattern of distribution when relative dominance is plotted against elevation (Fig. 5). *Tovara virginiana* is more abundant at the lower and higher elevation while *Parthenocissus quinquefolia* shows an affinity for the highest and the intermediate elevations.

We are indebted to Edward G. Voss for the identification of *Lindernia dubia,* which he reported "is not common northward, but it was collected 'about Alma' by C. A. Davis in the 1890's and in Midland County by R. R. Dreisbach. We have no specimens from any other county in the central part of

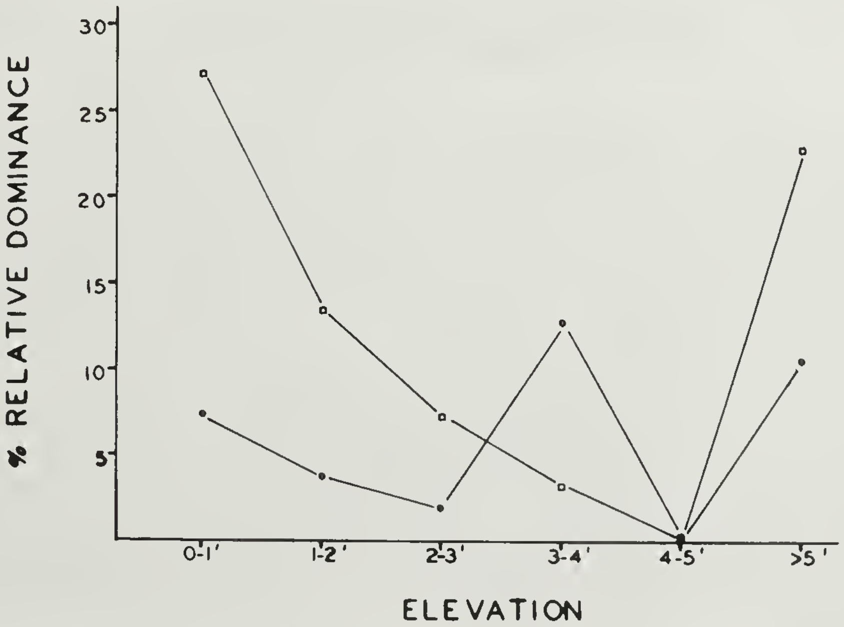

Fig. 5. Relative dominance of *Tovara virginiana* (squares) and *Parthenocissus quinquefolia* (circles) correlated with elevation.

the state (0nly one north of Midland County is from Gogebic!)." In the southeastern part of the state Voss observed "it is characteristic of recently exposed damp flats such as the Lake Erie shores when that lake went down and the banks of the Huron River at Geddes Pond after the dam went out."

Other ecological studies in the Saginaw Bay region have noted specific vegetational patterns and community types in the Pine River floodplain. Povich (1975) in an overview of the Pine River watershed defined five community types adjacent to the Pine River, these being:

White Cedar Swamp-Forest (*Thuja occidentalis* dominant)
White Cedar-Aspen-Forest (*Thuja occidentalis* and *Populus tremuloides* dominant)
Silver Maple-Ash-Elm-Forest (*Acer saccharinum-Fraxinus americana-Ulmus rubra* forest)
Upland Hardwood Forest (*Populus grandidentata-Acer saccharum-Quercus alba-Quercus rubra* forest)
Shrub Community (*Cornus racemosa-Alnus rugosa-Salix* community)

More intensive studies have shown the headwaters region to be dominated by *Thuja occidentalis, Populus tremuloides,* and *Betula papyrifera* (Allison, 1973). In the central section of the Pine River watershed, near the town of Alma, the floodplain forests are dominated by *Acer rubrum, Acer saccharinum,* and *Fraxinus americana* with appearance of some *Crataegus* species (Budge, 1974; Edgar & Wilson, 1974). Studies by Navarre (1976) have found the floodplains near the confluence of the Pine and Chippewa Rivers to be dominated by *Acer saccharinum, Fraxinus americana,* and *Salix nigra,* also having *Celtis occidentalis, Crataegus spp., Ulmus americana,* and *Acer negundo* present.

The dominant woody species of the Goetz Grove area are most similar to the segment of the Pine River watershed described by Navarre (1976) as the Hawthorn Community. *Crataegus* spp., *Celtis occidentalis, Ulmus americana,* and *Acer negundo* are common to the two areas. This similarity may be due to such factors as land use history, soil types and topographic relief; both sites are downstream in the watershed and close to a source of high industrial pollutants.

CONCLUSION AND SUMMARY

Fifty-five species of angiosperms were found at the Goetz Grove Nature Center in a late summer study in 1976. The most dominant were *Lysimachia nummularia, Crataegus* spp., *Vitis* spp., and *Carya cordiformis.*

Many of the species had affinity for a specific elevational level which would directly affect moisture availability. The selectivity in some instances was so specific that the probability of elevational correlation being due to chance was less than .001. This suggests that moisture availability is a determining factor in the vegetational patterns. It may be that extremely wet or dry years (the latter observed in 1977 when there was no standing water at any time during the growing season) are the key determinants of these distribution patterns.

The tolerance of a species to light intensity also proved to be a major factor involved in distribution. The probability of association of certain species with areas of low or high light intensity was found to be highly significant statistically.

While other factors such as variations in soil type, pollutant tolerance, and allelopathic relationships may also be significant, it is certain that tolerance to moisture availability and differing light intensities play a major role in the observed patterns of plant distribution.

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EASTERN HEMLOCK GERMINATION INFLUENCED BY LIGHT, GERMINATION MEDIA, AND MOISTURE CONTENT

Michael S. Coffman

Department of Forestry
Michigan Technological University
Houghton, 49931

Many forests in the Northeast and Lake States were originally dominated by *Tsuga canadensis* (eastern hemlock). Following extensive cutting, sites once dominated by hemlock were converted to northern hardwoods. A comprehensive study by Olson *et al.* (1959) revealed that eastern hemlock has a very narrow range of environmental conditions which are favorable to seed germination and initial establishment. It is possible, therefore, that the restrictive environmental requirements mentioned by Olson *et al.*, especially moisture deficits, are a major reason for the lack of eastern hemlock reproduction following the cutting of old-growth stands. Unfortunately, Olson *et al.* did not test enough moisture combinations to extrapolate to the natural forest system. The present study is an attempt to simulate certain conditions involved with germination in the natural environment by varying the germination media, relative humidity, and exposure to light energy and to determine the effects of these variables on germination.

Twelve treatments arranged in a randomized split plot design were established in growth chambers to test germinative capacity under different moisture and seedbed conditions. The major treatments consisted of two levels of light, .062 g-cal./min (4682 lux) and .009 g-cal/min. (645 lux). Seventy percent of this was from fluorescent light, and the remainder from incandescent lights. These conditions were imposed to simulate partial- and deep-shade conditions. In both cases day length was set at 10 hours to simulate natural conditions. Minor treatments consisted of three different germination media in 9 cm. petri dishes; loamy sand, shredded, partially decomposed yellow birch wood, and filter paper. The loamy sand was collected from the A_1 horizon of a hemlock site, while the partially decomposed birch wood was taken from a rotting log on which several hemlock seedlings were growing. The filter paper was used as a control to investigate further the importance of media for hemlock germination. Finally, one-half of the petri dishes used in each of the above treatments were loosely covered with lids in order to simulate conditions of nearly 100% relative humidity while the other half remained open. Each of the above treatments was replicated four times. Pans of water were placed in the chambers with the open petri dishes to raise the minimum relative humidity of the chambers to 70-80%.

All seed was collected in Baraga Co., Michigan. Dissection of 200 seeds showed seed viability to be 60%. All seeds were stratified in moist sand at 40° F for 60 days before being transferred to individual petri dishes. One hundred seeds were placed in each dish. During the study daytime temperatures and stratification conditions followed those found to be optimum for eastern hemlock by Olsen *et al.* Each treatment was watered with distilled water in a manner that would allow saturated germination media to dry to varying degrees before rewatering (Table 1). Moisture content of the germination media at various stages of drying (or watering) was determined by weighing and then comparing to oven-dry weight. The number of seeds germinated and the cumulative germination percentage was determined daily for 28 days.

The open petri dishes with a filter paper germination medium showed no germination during the entire study even though the seeds were watered twice a day (Table 2). Olson *et al.* found that a one-time drying for 12 hours at 70° F after stratification for 12 weeks had only a slight effect on germination of *Tsuga canadensis.* However, in this study drying was repeated twice daily for the entire 28 days. Apparently severe repeated drying, as

TABLE 1. Moisture of germination media in percentages before and after watering and the number of days between watering for the various treatments. (After watering percentages represent saturated conditions.)

	Before Watering				
	Moderate Light	Low Light	After Watering	Air dry	No. of Days Between Watering
Cover On					
Decomposed Birch	695.0	820.0	950	11.0	9
Sandy Loam Soil	21.0	22.0	28	0.2	6
Filter Paper	–	–	–	–	–
Cover Off					
Decomposed Birch	428.0	510.0	950	11.0	2
Sandy Loam Soil	0.2	0.3	28	0.2	½
Filter Paper	–	–	–	–	–

experienced in this treatment, created conditions completely unfavorable to germination.

At the other extreme, all treatments with covered petri dishes had rapid germination with the final germination percentage differences being non-significant (Table 2). Although the "birch wood" medium had consistently higher final germination percentages than the other media treatment, there were no significant differences between these treatments at any stage of the study. Under these conditions the germination media were always kept moist and the relative humidity of the air inside the petri dishes maintained near 100%. Apparently this environment represented ideal germinating conditions, and the germination media made little difference.

The greatest difference in percentage of germination between treatments occurred when the petri lids were left off (Figure 1; Table 2). The treatment using partially decomposed birch wood under low light and 70 to 80% humidity resulted in delayed germination initially, but the final germination percentages were comparable to results obtained when petri lids were in place (Figure 1). However, the same decomposed birch treatment exposed to moderate light exhibited delayed initial germination of several days and significantly reduced total germination to about one-half of that occurring under ideal conditions (Figure 1). Finally, a simulated mineral seedbed under moderate light with the same relative humidity resulted in much delayed germination with a significantly lower final germination of only one-third of that found under ideal conditions (Figure 1).

This order of decreasing germination generally follows the degree and frequency of drying before watering, that is, the greater and more frequent the drying, the lower the germination. For instance, the covered treatments were watered every six to nine days and were generally quite moist before watering, while the open treatments were watered as much as twice a day with much lower moisture contents prior to watering (Table 1). Within the open treatments under low light conditions there were potentially much lower

TABLE 2. Final germination percentages by treatment. Different treatments having a different letter represent significant difference (5% level) between treatments as determined by the Duncan Multiple Range Test.

	Percent Germination	
	Moderate Light	Low Light
Cover On		
Decomposed Birch	45.0 ab	44.0 ab
Loamy Sand Soil	37.2 ab	35.5 b
Filter Paper	42.8 ab	33.8 b
Cover Off		
Decomposed Birch	28.5 c	50.2 a
Loamy Sand Soil	12.8 d	28.3 c
Filter Paper	0 e	0 e

evaporation rates, hence there was a higher moisture content before watering than under high light conditions—i.e. the moisture contents of the germination medium were much less variable in low than in moderate light conditions (Table 1). Therefore, low light treatments had much better germination for the germination medium than did high light treatments (Figure 1). These results are supported by Olson *et al.,* who found that drying of stratified hemlock seed for extended periods of time slightly delayed the commencement of germination and the final germination percentages even though the seeds dried only once. Apparently repeated drying for varying times (as in this study) accentuates delay in commencement by creating negative water potentials within the seeds and sharply reduces final germination percentages. These adverse drying conditions were minimized in the birchwood treatment as compared to the mineral soil treatment. It would, therefore, be expected that germination would often occur only on shaded rotten logs in nature. Widespread reproduction of eastern hemlock on mineral soil would normally be found only during years of abundant seed and precipitation and under conditions of partial shade. As would be expected, these conditions occur only infrequently in the lake state region. Variations of this relationship have been noted by Willis & Coffman (1975), Stearns (1951), Graham (1941), Potzger (1936), and Gleason (1924). Conversely, sugar maple (*Acer saccharum*) regenerates aggressively in this region under a wide range of environmental conditions (Bourdo, 1968). It usually dominates advanced regeneration in old growth forests, even under dense hemlock stands (Willis & Coffman, 1975). It is, therefore, not surprising that even-aged sugar maple stands have typically replaced the old-growth hemlock after cutting during the first half of the century.

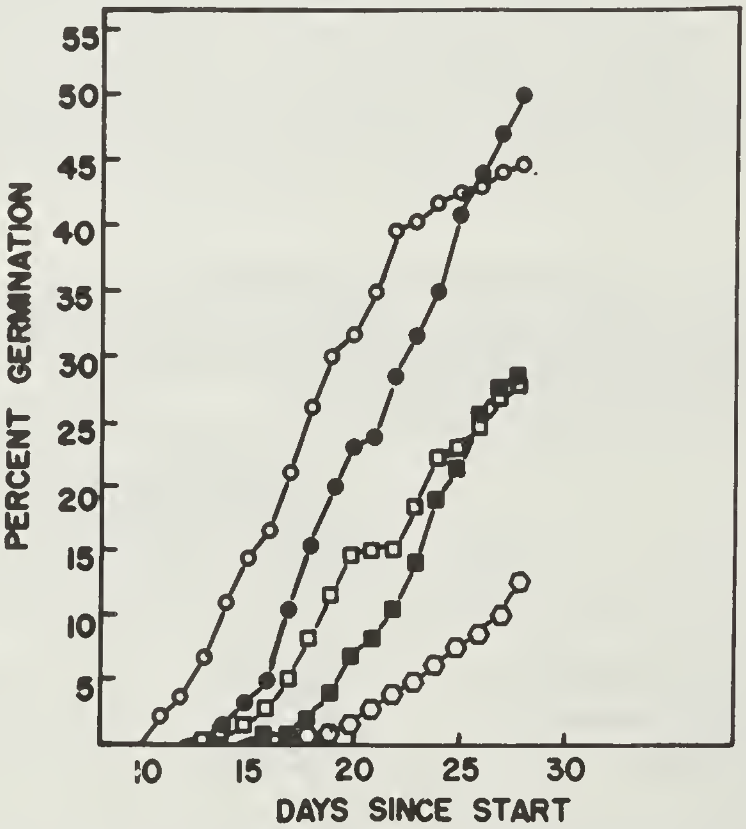

Fig. 1. Cumulative germination percent of selected treatments during the study. Moderate light, decomposed birch, ○—○; low light, decomposed birch, ●—●; low light, loam sand soil, □—□; moderate light, decomposed birch, ■—■; moderate light, loamy sand soil ○-○. All treatments except the first listed were uncovered.

In summary, the results of this study show that good germination of eastern hemlock occurs only when the seedbed is kept very moist. Any condition of drying, in frequency or severity, will substantially reduce germination percentages. Increased exposure following heavy cutting of hemlock, as frequently practiced in the Upper Peninsula of Michigan and elsewhere in the Northern Hardwood Region, normally results in increased drying of the soil surface, in frequency and severity. Furthermore, even in lightly cut stands the conditions of having both a heavy seed year and above normal precipitation occur only infrequently. This fact may provide a partial explanation of why eastern hemlock is rarely found in second-growth stands following cutting or other major disturbances of virgin hemlock forests.

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BRUCE FINK'S LICHEN COLLECTIONS IN MINNESOTA

Clifford M. Wetmore

Botany Department
University of Minnesota, St. Paul, 55108

Between 1896 and 1902 Bruce Fink spent time in Minnesota collecting and studying the lichens of the state for his Ph.D. degree and as part of the Botanical Survey of Minnesota. He published a series of articles on the lichens of different parts of the state (Fink, 1896, 1897, 1898, 1899a, 1899b, 1901, 1903a, 1903b). Parts IV and V (Fink, 1899a, 1899b) of these preliminary papers formed his Ph.D. thesis and the degree was granted by the University of Minnesota in 1900. The thesis in the University archives is a bound copy of these two reprints. Fink revised these preliminary papers and published them as *The Lichens of Minnesota* (1910).

Fink collected about 5500 lichens in Minnesota for these studies at numerous localities scattered over the state (Fig. 1). A complete set of these collections is in the University of Minnesota herbarium (MIN), and a representative set is in his personal herbarium which was acquired by the

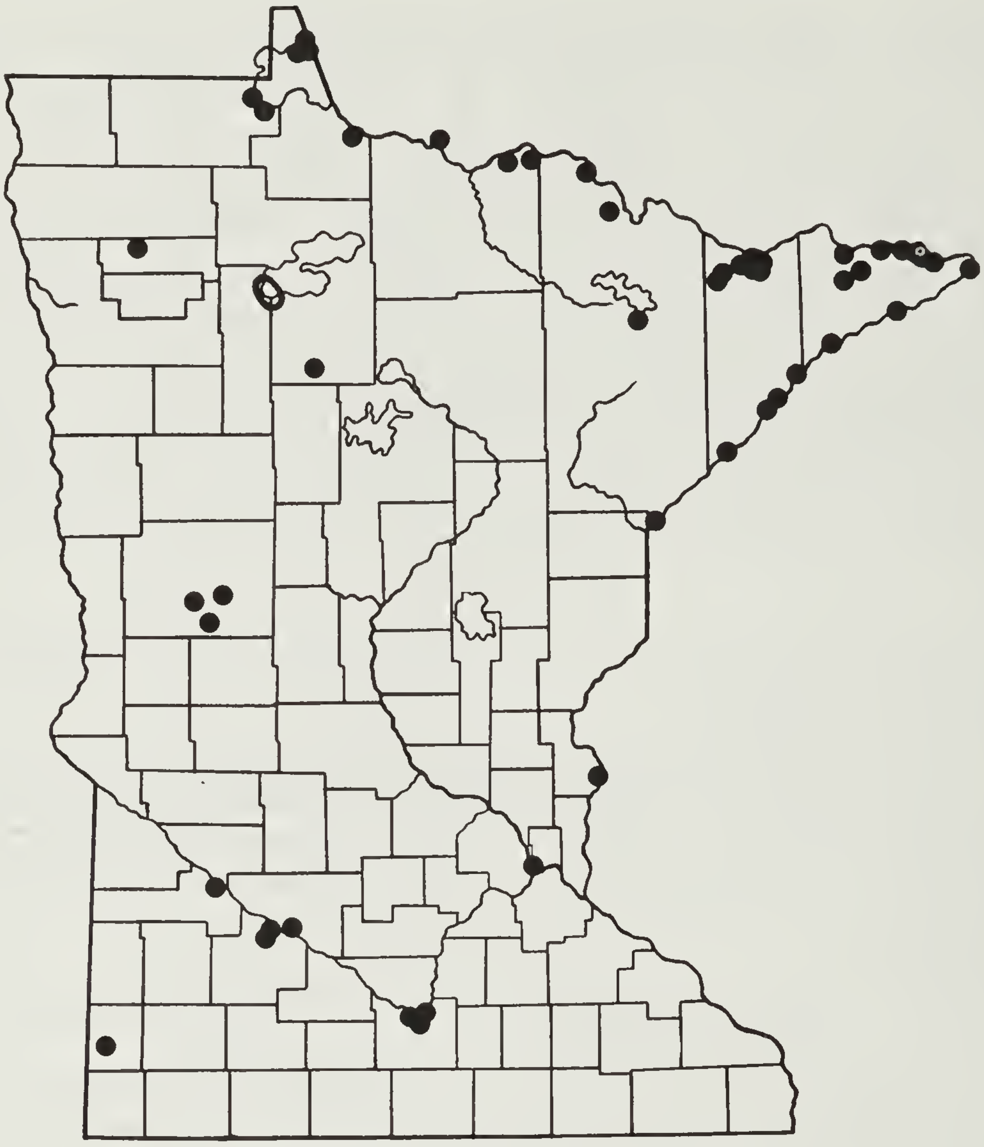
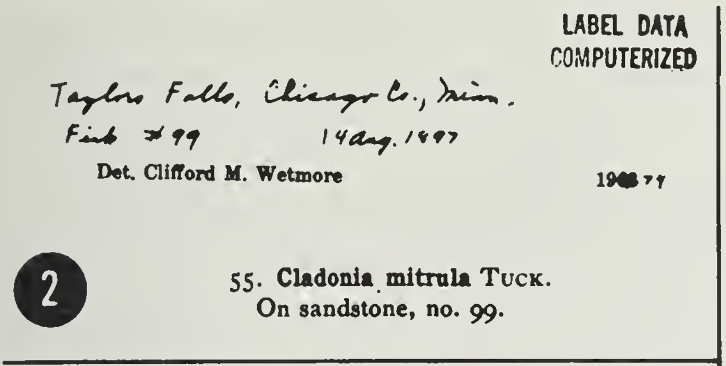


Fig. 1. Map of Fink's collection localities in Minnesota. Area indicated by the oval cannot be located more accurately.

University of Michigan (MICH) after his death. Duplicates were widely distributed and are often cited in monographic papers. The labels have only brief locality names, and there is some confusion about his collection numbers. Some of the locality names are not on present maps or are difficult to find, and no counties are given. This report is presented to supplement the label data on the collections to aid in future reference to them.

The first step in sorting out Fink's localities was to produce a listing of his Minnesota collections based on the specimen labels in this herbarium. Since all of the label data from our lichen collections had been computerized, it was easy to print out a list of species with localities arranged by date. The collection numbers generally followed the date sequence within each year. This list was studied for inconsistencies in localities or collection numbers with respect to dates. The specimen labels were rechecked to correct for keypunching and interpretation errors. The person who prepared many of the labels (often not Bruce Fink) wrote some numbers in such a way as to be easily misread (Fig. 6, 7). Fink's publications were then checked and the specimen citations compared with the computer printout of the label data. When both the published data and the computer generated itinerary indicated an error on the label, the label was annotated giving the presumed correct information, and the computer data base was corrected. For the 1902 labels in which no collection numbers were used, but the Hibbard photograph

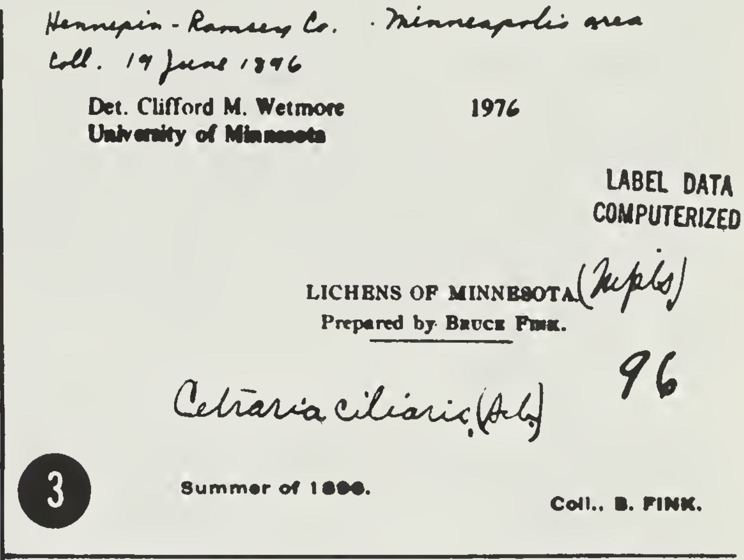


LABEL DATA
COMPUTERIZED

Taylors Falls, Chisago Co., Minn.
Fink #99 14 Aug. 1897
Det. Clifford M. Wetmore 19[illegible]77

2

55. Cladonia mitrula Tuck.
On sandstone, no. 99.



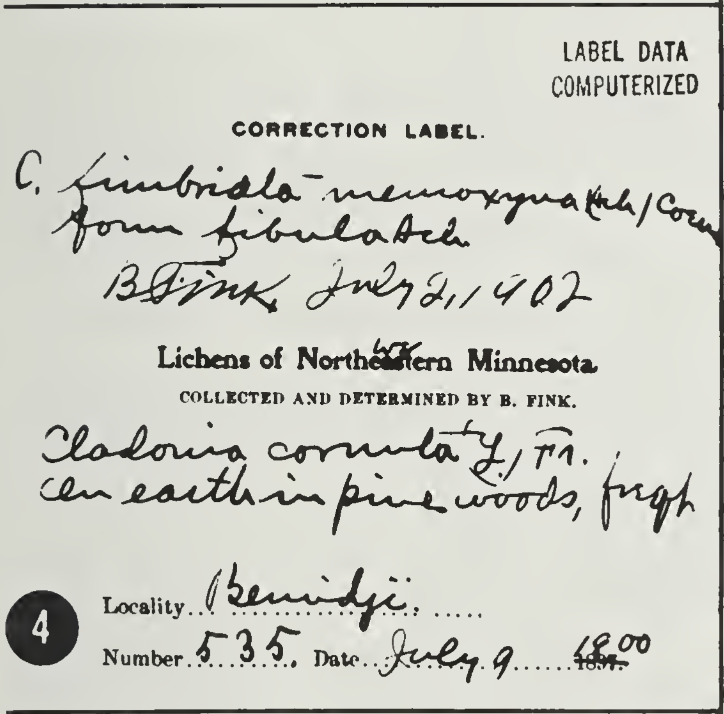
Hennepin-Ramsey Co. · Minneapolis area
Coll. 19 June 1896
Det. Clifford M. Wetmore 1976
University of Minnesota

LABEL DATA
COMPUTERIZED

LICHENS OF MINNESOTA (Mpls)
Prepared by Bruce Fink.
96
Cetraria ciliaris (Ach.)

3

Summer of 1[illegible].
Coll., B. FINK.



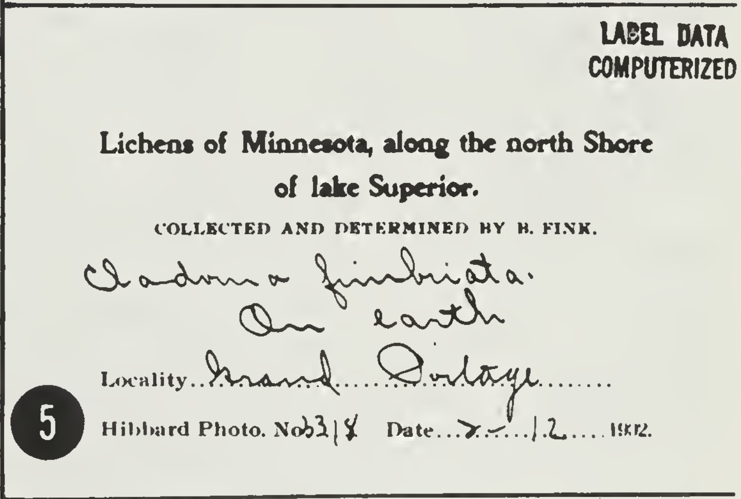
LABEL DATA
COMPUTERIZED

CORRECTION LABEL.
C. fimbriata-nemoxyna Ach./Corn.
form fibula Ach.
B Fink July 2, 1902

Lichens of North~~eas~~western Minnesota.
COLLECTED AND DETERMINED BY B. FINK.
Cladonia cornuta (L.) Fr.
On earth in pine woods, freq.

4

Locality Bemidji.
Number 535. Date July 9 ~~1897.~~ 1900

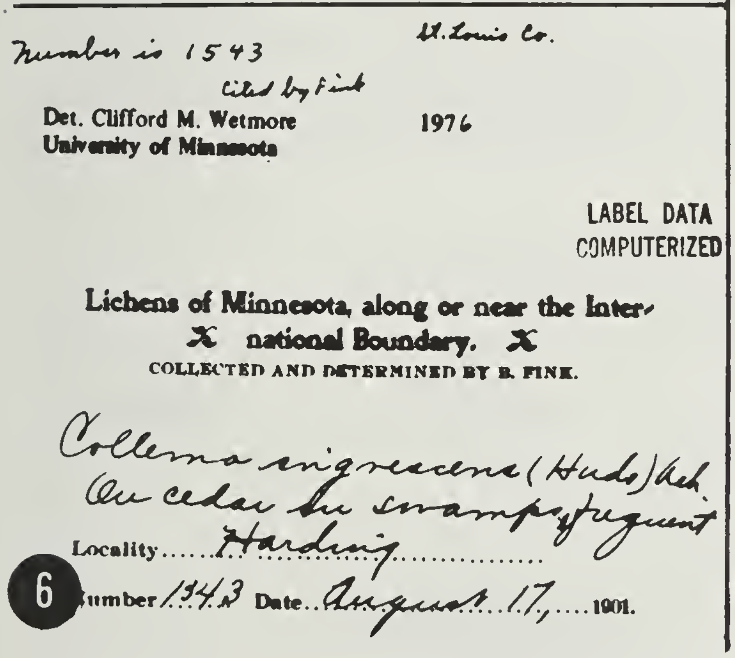


LABEL DATA
COMPUTERIZED

Lichens of Minnesota, along the north Shore
of lake Superior.
COLLECTED AND DETERMINED BY B. FINK.
Cladonia fimbriata.
On earth

5

Locality Grand Portage
Hibbard Photo. No 3318 Date 7-12 1902.



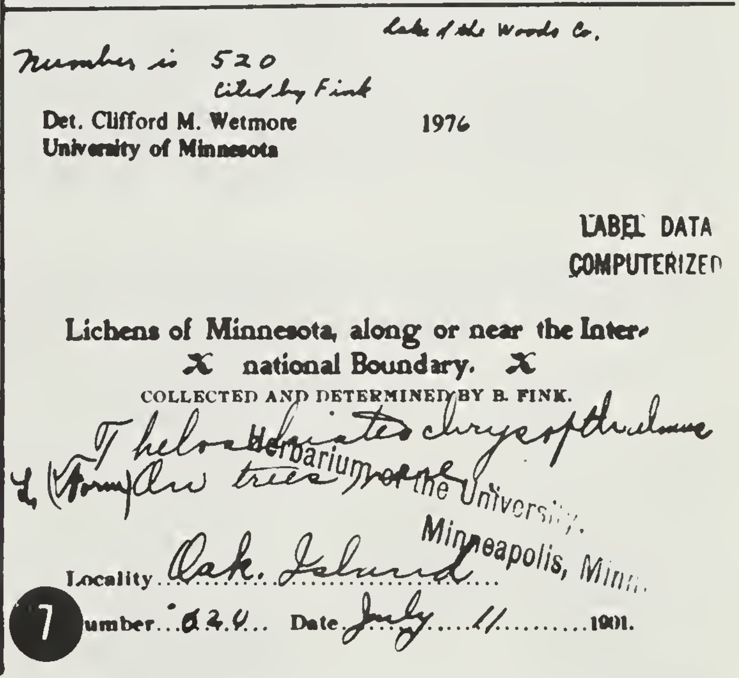
St. Louis Co.
Number is 1543
cited by Fink
Det. Clifford M. Wetmore 1976
University of Minnesota

LABEL DATA
COMPUTERIZED

Lichens of Minnesota, along or near the Inter-
✕ national Boundary. ✕
COLLECTED AND DETERMINED BY B. FINK.
Collema nigrescens (Huds.) Ach.
On cedar in swamps, frequent
Locality Harding

6

Number 1543 Date August 17, 1901.



Lake of the Woods Co.
Number is 520
cited by Fink
Det. Clifford M. Wetmore 1976
University of Minnesota

LABEL DATA
COMPUTERIZED

Lichens of Minnesota, along or near the Inter-
✕ national Boundary. ✕
COLLECTED AND DETERMINED BY B. FINK.
Theloschistes chrysophthalmus
(L.) (Form) On trees
Herbarium of the University,
Minneapolis, Minn.
Locality Oak Island

7

Number 520 Date July 11 1901.

Fig. 2-7. Fink lichen labels in MIN. 2. Label cut from reprint for Taylors Falls locality. 3. Label for Minneapolis localities. 4. 1897 label used for 1900 collection and corrected. Bruce Fink's handwriting. 5. Label for 1902 collections with Hibbard photograph number. 6-7. Collection numbers easily misinterpreted with corrections on annotation slips.

numbers are given, the index book of Hibbard photographs was checked for further information. The localities were then located on state and county maps as far as possible (Fig. 1). Other sources of information checked were Upham (1920), Winchell (1899), the University of Minnesota Archives, and Elftman's original field notebooks. I have been unable to locate any of Fink's collection books or field notebooks for these Minnesota collections at the University of Michigan, the University of Minnesota herbarium and archives, the Minnesota Geological Survey, or the State of Minnesota Historical Society Archives. There must have been some sort of notebooks because some habitat and locality information given in Fink's publications is not on the labels, and some labels prepared later for duplicate specimens have information not on the original labels in MIN. Also, no other botanical field books for the Botanical Survey (e.g., MacMillan, Arthur, Holzinger) have been located. These books may have been deposited with the state Geological and Natural History Survey and since lost.

The final itinerary was then prepared. Table 1 gives the dates and collection numbers for each locality. Counties have been added, but more precise location as to township, range and section or latitude and longitude have not been added since in most cases the locality information available today is inadequate for more exact location, and the localities are only general areas anyway. It should be noted that Fink's numbers started over each year, and so it is necessary to cite both number and year.

Bruce Fink's first collecting in Minnesota was around Minneapolis in the summer of 1896. The exact localities are unknown but include an area "within 6 miles of the city limits" as of 1896 which includes parts of both Hennepin County and Ramsey County. He visited habitats in tamarack swamps and the river bluffs, but it is unlikely that many of the lichens found by Fink occur in this area today since no tamarack swamps now exist there, and the city extends all along the river. The labels for these collections (Fig. 3) have "Mpls" and the collection number but no exact dates; however, the exact dates are given in his paper (Fink, 1897). On 15 August 1896 Fink also visited Taylors Falls 40 miles northeast of Minneapolis and collected on the

TABLE 1. Collection localities of Bruce Fink in Minnesota, 1896-1902.

Dates	Locality	County	Collection Numbers
1896			
19, 24-26, 28, 30 June, 2-4, 7-14, 16, 18, 20, 30-31 July	Minneapolis area	Hennepin-Ramsey	1-230
15 Aug.	Taylors Falls	Chisago	1-92
1897			
16-24 June	Grand Portage, Mt. Josephine, Grand Portage Island, Hat Point	Cook	1-189
26 June	Portages along International Boundary to South Fowl Lake, English Portage	Cook	190-192
26 June	South Fowl Lake and portage at south end	Cook	193-208

TABLE 1. Continued

Dates	Locality	County	Collection Numbers
27-29 June	Rose Lake and portage to Rove Lake	Cook	209-230
30 June-2 July	Gunflint: Paulson iron mine, Gunflint Lake	Cook	231-401
3-5 July	Misquah Hills: Winchell Lake, Brule Lake	Cook	403-545
10, 12 July	Tofte, Carlton Peak	Cook	546-659
13-15 July	Beaver Bay	Lake	660-742, 777-786
15 July	Palisades	Lake	742-776
17 July	Two Harbors	Lake	787-802
19-27 July	Snowbank Lake area: Prairie Portage, Iron Mountain Lake, Snowbank Lake, Disappointment Lake, Moose Lake, Wind Lake	Lake	803-974
28 July	Ely: Ella Hall Lake, Fall Lake	Lake	976-1022
14 Aug.	Taylors Falls	Chisago	93-119
1899			
22-26 June	Mankato	Blue Earth	1-134
27 June	Minneopa	Blue Earth	135-157
28 June	Rapidan	Blue Earth	158-187
29 June-1 July	Mankato	Blue Earth	188-221
3-5 July	New Ulm	Brown	222-300
6 July	Redwood Falls	Redwood	301-310
7 July	Morton	Renville	313-325
8 July	Redwood Falls	Redwood	326-360
10 July	North Redwood	Redwood	361-371
11-15, 17 July	Granite Falls	Yellow Medicine	372-588
18-19 July	Pipestone	Pipestone	589-644
1900			
18-23 June	Battle Lake	Otter Tail	1-169
25 June	Henning	Otter Tail	170-200
26-27 June	Leaf Hills	Otter Tail	201-296
28-30 June	Henning	Otter Tail	298-383
2 July	Leaf Hills	Otter Tail	385-404
2 July	Henning	Otter Tail	406-416

TABLE 1. Continued

Dates	Locality	County	Collection Numbers
4-14, 16 July	Bemidji	Beltrami	419-750
17-21, 23 July	Thief River Falls	Pennington	751-874
26-28, 30 July-4 Aug.	Red Lake	Beltrami or Clearwater	879-1083
1901			
18-22, 24 June	Baudette	Lake of the Woods (and Ontario, Canada?)	1-146
25-29 June, 1-5 July	Warroad	Roseau	148-385
6 July	Le Claire	Lake of the Woods	380-384
8-11 July	Oak Island	Lake of the Woods	385-526
12 July	Flag Island	Lake of the Woods	529-561
13 July	Blueberry Island	Lake of the Woods	562-609
15 July	Oak Island	Lake of the Woods	610-625
16 July	Mainland, opposite Oak Island	Lake of the Woods	626-635
17-20, 22-24 July	Emo	Ontario, Canada	637-857
25-27, 29-31 July	Koochiching (= International Falls)	Koochiching	858-1059
1-3, 5-8 Aug.	Rainy Lake City	Koochiching	1062-1313
9-10, 12-15 Aug.	Kettle Falls	St. Louis	1314-1496
16-17, 19-21 Aug.	Harding	St. Louis	1497-1668
23-24, 26-29 Aug.	Tower	St. Louis	1669-1886
1902			Hibbard Photo
1 July	Minneapolis	Hennepin	–
17 July-5 Aug.	Grand Marais	Cook	5100-5314
9 Aug.	Isle Royale, Mich.	Keweenaw	5315-5316
12-18 Aug.	Grand Portage, Hat Point	Cook	5318-5371
20-23 Aug.	Tofte	Cook	5372-5400
25-29 Aug.	Pork Bay, Thomasville	Lake	5402-5438
1 Sept.	Grand Marais	Cook	–
6 Sept.	Edgewood/Auburndale (Duluth)	St. Louis	5440-5446
8 Sept.	Edgewood/Auburndale (Duluth)	St. Louis	5447-5456
9 Sept.	Edgewood/Auburndale (Duluth)	St. Louis	5457-5469

Minnesota side of the St. Croix River in Interstate Park. This same locality was again visited on 14 August 1897. These two sets of collections from Taylors Falls are in one collection number series with 1 to 92 collected in 1896, and 93 to 119 collected in 1897. The labels on the specimens from Taylors Falls and some from Minneapolis area in MIN are only cut out portions of the published report (Fig. 2) but without indicated locality or date.

Fink's first extended collecting trip in Minnesota was as a member of a geological survey group in the northeastern part of the state in the summer of 1897. Dr. A. H. Elftman was the geologist on the trip and Mr. A. S. Skinner was a field assistant. The group spent ten days around Grand Portage then traveled along the Pigeon River at the Canadian border to Gunflint Lake, south to Lutsen on Lake Superior then southwest along the shore to Beaver Bay. They then went directly to Ely and visited several lakes east of Ely. The localities given on most of the labels are for the nearest well studied locality even for those lichens picked up in transit. The names given for some localities are not on present maps or have been changed, but by referring to Elftman's field notebooks and the final geological report (Winchell, 1899), all of the localities mentioned have been located. "Paulson iron mines" is in Sec. 29, T65N, R4W, four miles west of the west end of Gunflint Lake in Cook County on the north side of what is now called Mine Lake. "Misquah Hills" refers to collections made at Winchell Lake and Brule Lake in north-central Cook County. "Palisades" is now called Palisade Head and is two miles northeast of Silver Bay on Lake Superior. "Iron Mountain Lake" is now called Ensign Lake and is directly north of Snowbank Lake in Lake County, 22 miles northeast of Ely. Probably almost all specimens collected at localities recorded on labels as "Ely" (which is in St. Louis County) were actually collected around lakes east of Ely and were from Lake County.

Some labels from this 1897 expedition were used for collections in 1900. In most cases the heading and year were changed by pen (Fig. 4), although some escaped correction. Reference to the table should clear up any doubtful cases. There is no evidence that Fink collected outside of Cook or Lake Counties and Taylors Falls in 1897.

The second extended collection season was in 1899 when Fink visited southwestern Minnesota. He collected around Mankato and other towns along the Minnesota River and at Pipestone in the southwestern corner of the state. "Minneopa Falls" is on the Minnesota River four miles west of Mankato. Rapidan is a small town four miles south of Mankato. Morton is on the river just east of Redwood Falls, and North Redwood is on the river northeast of Redwood Falls.

In 1900, about the time he received his degree and presumably the time when the accompanying portrait (Fig. 8) was made, Fink collected in west-central and north-central Minnesota. His paper on the region (Fink, 1901) refers to collecting in Otter Tail, Beltrami and Red Lake Counties. Pennington County was established as a separate county from Red Lake County in 1910, and Beltrami County in 1900 included what is now Clearwater County (divided in 1902). The "Battle Lake" localities were

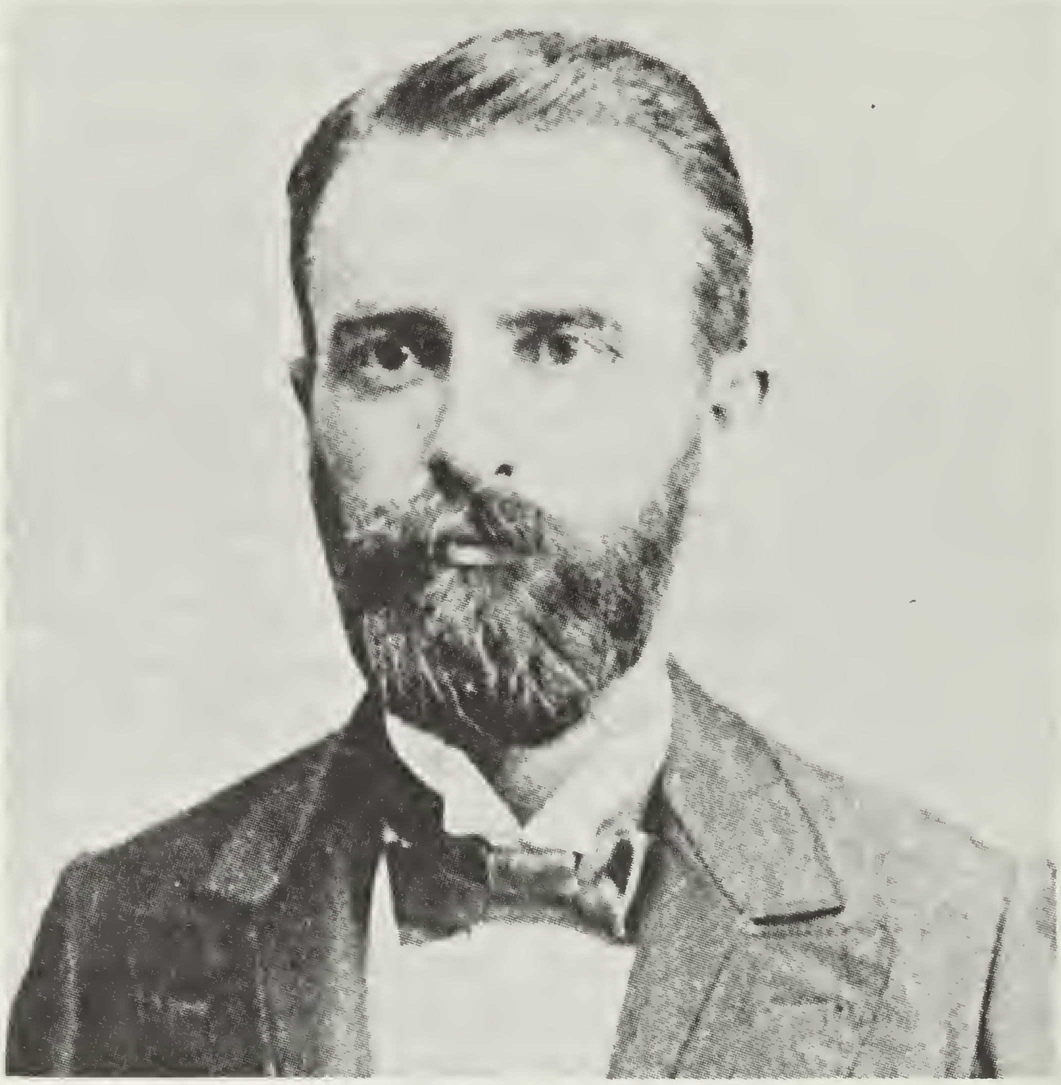


Fig. 8. Photograph of Bruce Fink taken about 1900 (from a print found at Upper Iowa College, Fayette, Ia.).

around the moraines south of the town. "Leaf Hills" refers to the moraines south of Henning and Vining in the south-central part of Otter Tail County. Black Peak is a high point in the Leaf Hills. At the Bemidji locality there is a duplicate series of numbers between 505 and 522. Fink collected on the shore of Red Lake 36 miles north-northwest of Bemidji and 65 miles east-southeast of Thief River Falls. This locality was probably along the southwest shore of Lower Red Lake and probably now in Clearwater County, but nothing can be found to locate it more exactly. Old maps show a road going to shore on the west side of the lake (Beltrami County) and a railroad going to shore on the south side (Clearwater County), and so Fink had access to Red Lake at either place.

In 1901 Fink spent 11 weeks with the Botanical Survey along the northern border of the state from Lake of the Woods east and south to Tower (north of Duluth). The town "Beaudette" is now spelled Baudette, and some of the collections from this locality may actually have come from Canada. The rock outcrop he mentioned between Warroad and Roosevelt was not found on a recent trip to the area by one of my graduate students, Thomas Trana, and may have been destroyed by new highways. Le Claire is on the Lake of the Woods on the mainland across from Oak Island, but I have not been able to locate it more exactly. The numbers from this locality are duplicates of those used at Warroad (380-384). Oak Island, Flag Island and

Blueberry Island are in the Lake of the Woods. The collections at Emo were made in Ontario, Canada, and may include collections from Boucherville, Ontario. "Koochiching" is now called International Falls and is on the west end of Rainy Lake. "Rainy Lake City" is no longer a town but was located in the northwestern corner of Voyageurs National Park on the Kabetogama Peninsula directly east of the present town of Island View (11 miles east of International Falls). Kettle Falls is at the eastern end of Rainy Lake opposite Oakpoint Island (Canada). Harding is on the southwest corner of Crane Lake in St. Louis County (52 miles north of Virginia).

In 1902 Fink returned to the north shore of Lake Superior with Mr. C. J. Hibbard, a professional photographer. Hibbard photographed lichens in the field under Fink's direction, and then Fink collected the lichens as vouchers. The herbarium labels for these have the Hibbard photograph numbers instead of collection numbers (Fig. 5). Many of these photographs were published in Fink's *Lichens of Minnesota* and reprinted in his *Lichen Flora of the United States.* The original negatives and prints for all these photographs are on file at MIN and represent one of the earliest set of vouchered photographs made. Fink and Hibbard went to Isle Royale, Michigan, and got at least as far as Rock Harbor since there is a photograph of Bruce Fink at the Rock Harbor lighthouse (Fig. 9). Some time was spent at Hat Point (at Grand Portage) and on down along the shore toward Duluth. "Pork Bay" is a small bay one mile

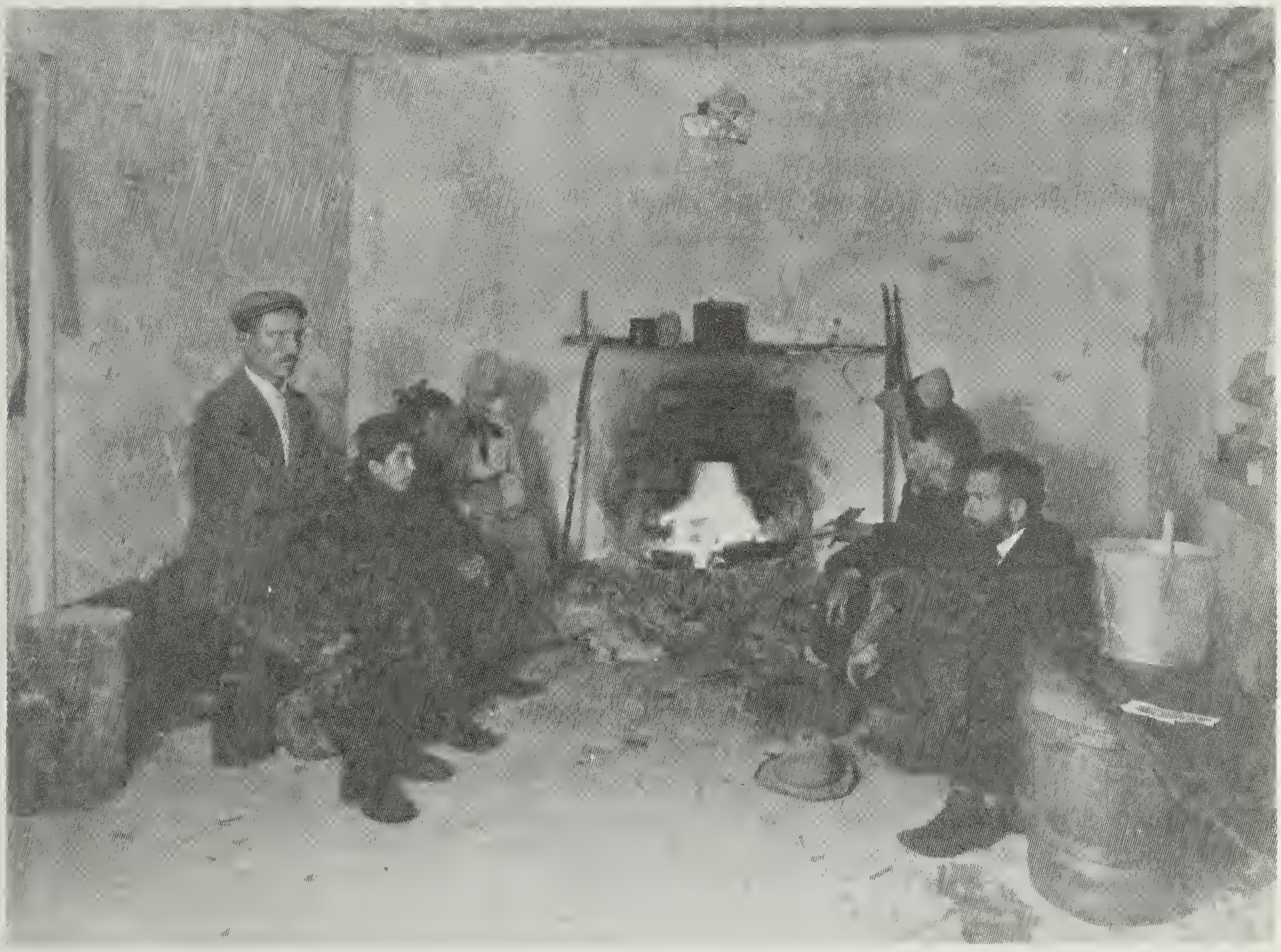


Fig. 9. The Minnesota Botanical Survey party on Isle Royale (Michigan), at Rock Harbor Lighthouse. Fink is the front man on the right. (From a photograph at the University of Michigan Herbarium, taken by C. J. Hibbard about 9 August 1902.)

west of the eastern Lake County line by the Little Manitou River on the shore of Lake Superior. The locality "Thomasville" cannot be found, but it probably is in Lake County near Pork Bay. Fink (1903a) referred to the Sawteeth Mountains and Howenstine Bluff which are on the shore near Grand Marais (the former is one mile north, the latter one mile west). Some collections were made at a locality listed on the labels as "Auburndale" and listed in Hibbard's record book as "Edgewood, Duluth." This locality must be in or near Duluth, but I have not been able to locate either name on any old map or in any old reference.

The itinerary and information presented here should aid in mapping and citing Fink's Minnesota collections. Additional information may lead to some minor revisions. Inquiries are invited from lichenologists on specific collections that present discrepancies. The availability of the computerized label information makes the generation of such itineraries readily available and provides information on specific collections. All the lichens in the University of Minnesota herbarium have been computerized, and this is just one example of the type of retrieval that is available. Further discussion on the computer system and other types of retrievals will be covered in a later paper.

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INVESTIGATIONS ON THE FRESHWATER ALGAE OF WISCONSIN I. PLANKTON DIATOMS FROM HIGH LAKE (VILAS COUNTY)

Louis L. Lipsey, Jr.
Department of Botany
Southern Illinois University
Carbondale, 62901

Mason G. Fenwick
Department of Biological Sciences
Northern Illinois University
DeKalb, 60115

The most numerous accounts of freshwater algae occurring in Wisconsin are included in the early investigations of Smith (1916a, 1916b, 1918, 1920, 1924) and Prescott (1944, 1962). In recent years, however, work by Boylen & Brock (1974), Gough & Woelkerling (1976), King (1975), Sloey & Blum (1972), Woelkerling (1975, 1976), and Woelkerling & Gough (1976) have increased our knowledge of the state's algal flora. Although there appears to be a wealth of information on the freshwater algae of Wisconsin, the diatoms (Bacillariophyceae) have been more or less neglected. This paper represents a preliminary survey of a diatom flora found in a small lake in the northeastern lake district of Wisconsin. Fifty-eight diatom records are reported from this region for the first time.

Planktonic diatoms were collected from 13 major sampling sites on High Lake in Vilas County on May 12, July 6, and August 9, 1975. Eight sites were located within the littoral zones of the lake, while the remaining five were more representative of the limnetic zone (Figure 1). At each site two samples were collected using a one-liter Kemmerer water sampler: one just below the lake surface and the second approximately one meter above the bottom. The water depth varied from 2.4 to 11.5 m at the various sites, and the substrates ranged from muck to silt-sand to rock-gravel. In the laboratory the samples were poured into 500 ml graduated cylinders, and then 4 ml of Lugol's solution were added to each cylinder to aid in the settling process. After 48 hours, all samples were concentrated 10 times, 5 times, 2.5 times, or 1.25 times depending on turbidity. Fifteen drops (0,75 ml) were obtained from each concentrated sample and carefully placed on a 2.2 cm^2 glass coverslip. All coverslips were then heated at 500° C to remove by incineration the organic matter. After incineration, the coverslips were inverted on Carmount mounting medium for microscopic examination. All taxa were identified and counted under the oil immersion lens of an Olympus, phase-contrast, light microscope. Hustedt (1930) and Patrick & Reimer (1966, 1975) were the primary sources used to identify the various taxonomic entities. The study material has been deposited in the senior author's private research collection.

High Lake is located 8.1 km northeast of the village of Boulder Junction (Township 42.43 North; Range 7, 8 East; Section 36, 31, 32.16; Town of Presque State Line, Boulder Junction, Vilas County). The lake has a surface area of 310 ha, a total shoreline of 10.6 km, and a maximum depth of 11.5 meters.

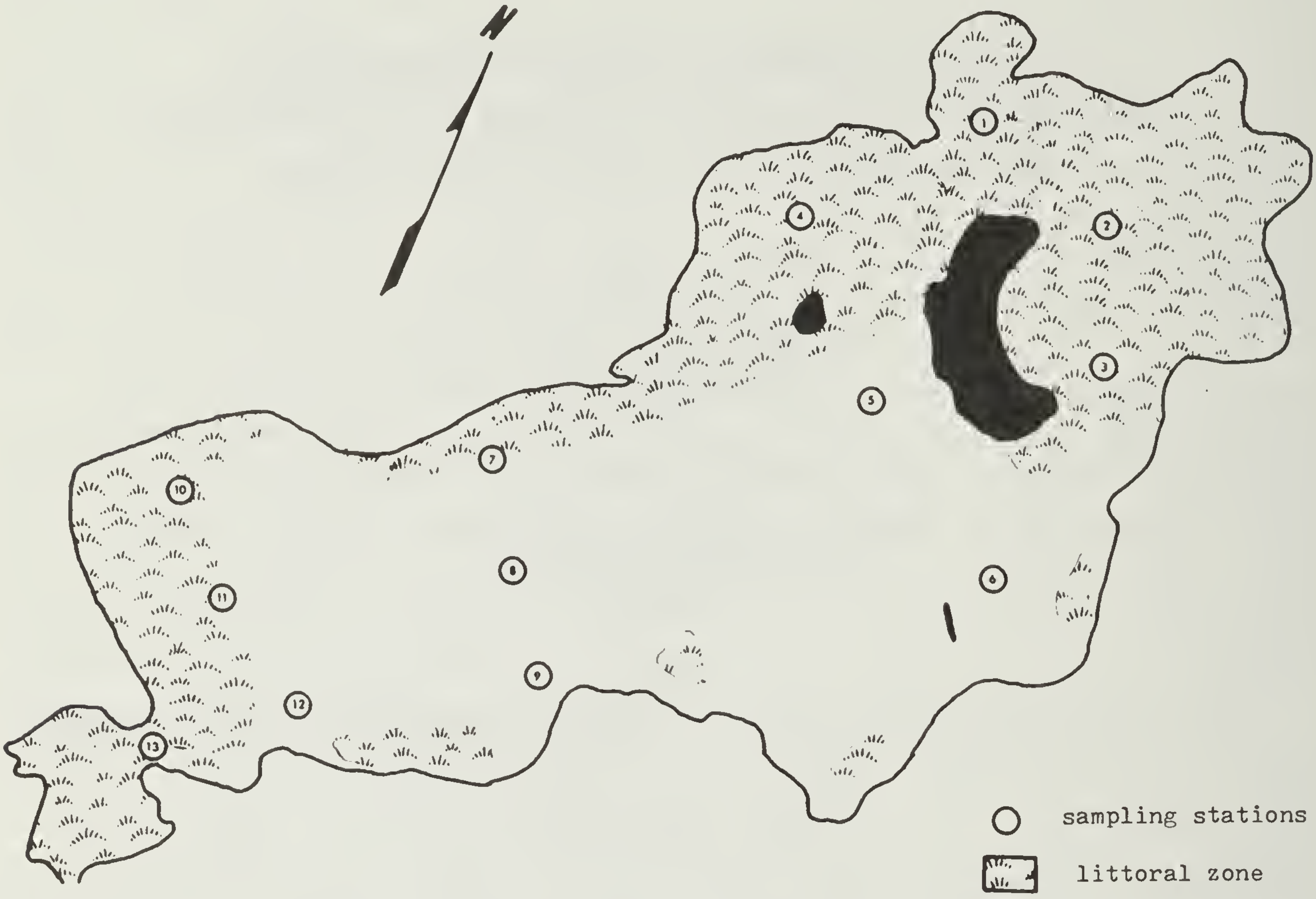

Fig. 1. High Lake, Vilas County, Wisconsin. The surface area of the lake is 310 ha. (Three islands are represented by darkened areas.)

It is a dimictic hard-water drainage lake located in the northeastern Wisconsin lake district within the Northern Highland. It is glacial in origin and serves as headwater of the famed Manitowish River. The shores of the lake do not rise more than a few meters above the surface of the water; they are composed of sand, gravel, boulders, and clay in varying proportions. The underlying formation consists entirely of Precambrian granites. Overlying this is a mantle of glacial drift varying from 23 to 30 m in thickness (Juday & Birge, 1941). The glacial accumulation is not the result of one ice invasion, but of several. The last, and the one which is believed to have left the bulk of the material, came from the northeast (from the sandstone region of northern Michigan) and probably transported the many conspicuous sand deposits observed in this area. Second-growth pine and deciduuous forest cover the glacial mantle.

In 1913, E. A. Birge (who at the time was Director of the Wisconsin Geological and Natural History Survey) extended an invitation to G. M. Smith to undertake a phycological study of the lakes of Wisconsin. Between 1913 and 1917, Smith visited all the major lake areas of the state at least once. Limitations confined his studies to the phytoplankton only, and the results were recorded in a number of periodicals (Smith, 1916a, 1916b, 1918). In 1920, the Wisconsin Geological and Natural History Survey issued Smith's report on the "Phytoplankton of the Inland Lakes of Wisconsin." This report included all of the planktonic algae except those in the Desmidiaceae and

Bacillariophyceae. Within a few years Smith (1924) published a similar bulletin (Part II) on the Desmidiaceae. In this work he mentioned that a third part, including the Bacillariophyceae, had been sent for review and study to F. Meister of Zürich. This manuscript has never been published, and its whereabouts is unknown (according to Dr. Ruth Patrick, Academy of Natural Sciences, Philadelphia, PA).

The earliest study dealing with the diatom flora of Wisconsin, and probably the most extensive study to date, was presented by Conger (1939). He studied 32 sediment core samples taken from Crystal Lake, Vilas County, from which he identified 23 genera and 85 species of diatoms. He noted that the species which most often dominate the deep water sediments of a lake (e.g., *Melosira granulata* and *Stephanodiscus niagarae*) were rare in the sediments of Crystal Lake. The flora, in general, was heterogeneous in nature, and Conger suggested that the distribution of the dominant taxa changed in response to variations in the lake's environment. Late Pleistocene diatoms were investigated by Andrews (1966) from the Hixton diatomite deposit found by him near the Trempealeau Valley in southern Wisconsin. Andrews reported 73 species and varieties from this region. Sloey & Blum (1972) observed 68 diatom species in their study of the Winnebago Pool (Lakes Winnebago, Poygan, Winneconne, and Butte des Morts) in east-central Wisconsin. Population dynamics of the dominant phytoplankton organisms were presented, and the productivity of the various lakes discussed in regard to 106 plankton taxa. Winter blooms of *Cymbella* were studied in Lake Wingra by Boylen & Brock (1974). The most recent paper involving Wisconsin diatoms, presented by King (1975), encompassed the western portions of the state; only six edaphic taxa were found. Species identification was not performed, and the results were inconclusive.

Following is a checklist to the phytoplankton diatoms (Chrysophyta: Bacillariophyceae) from High Lake, Vilas County. An asterisk indicates records new for Vilas County (and the northeastern lake district). Nomenclature follows that of Hustedt (1930) and Patrick & Reimer (1966, 1975). Taxa are arranged according to the plan used by Lipsey (1975).

Coscinodiscaceae

*Melosira ambigua (Grun.) O. Müll.
M. granulata (Ehr.) Ralfs in Pritch. var. granulata
*M. granulata var. angustissima O. Müll.
Cyclotella comta (Ehr.) Kütz.
*C. stelligera (Cl. & Grun.) V. H.
*Stephanodiscus hantzschii Grun. in Cl. & Grun.
*S. minutus Grun. ex Cl. & Möller
S. niagarae Ehr.

Rhizosoleniaceae

*Rhizosolenia eriensis H. L. Smith

Fragilariaceae

*Asterionella formosa Hass.
Fragilaria construens (Ehr.) Grun. var. construens
*F. construens var. binodis (Ehr.) Grun.
*F. construens var. subsalina Hust. in Thienemann
*F. construens var. venter (Ehr.) Grun.
*F. crotonensis Kitton
F. pinnata Ehr.
*Synedra capitata Ehr.
*S. cyclopum Brutschy
*S. minuscula Grun. in V. H.
*S. radians Kütz.
*S. rumpens Kütz.
Tabellaria fenestrata (Lyngb.) Kütz.

Eunotiaceae

*Eunotia curvata (Kütz.) Lagerst.
*E. diodon Ehr.
*E. formica Ehr.

Achnanathaceae

*Achnanthes conspicua A. Mayer
*A. exigua Grun. in Cl. & Grun.
*A. lanceolata (Bréb.) Grun. in Cl. & Grun. var lanceolata
*A. lanceolata var. dubia Grun. in Cl. & Grun.
*A. microcephala (Kutz.) Grun. in Cl. & Grun.
*Cocconeis pediculus Ehr.
*C. placentula var. lineata (Ehr.) V. H.

Naviculaceae

*Amphipleura pellucida (Kütz.) Kütz.
*Diploneis elliptica (Kütz.) Cl.
Navicula anglica Ralfs in Pritch.
*N. cryptocephala Kütz. var. cryptocephala
*N. cryptocephala var. veneta (Kütz.) Rabh.
N. cuspidata (Kütz.) Kütz.
*N. elginensis (Greg.) Ralfs
*N. gastrum (Ehr.) Kütz.
*N. graciloides A. Mayer
*N. longirostris Hust.
*N. mournei Patr.
*N. pupula var. rectangularis (Greg.) Grun.
N. radiosa Kütz. var. radiosa
*N. radiosa var. parva Wallace
*N. radiosa var. tenella (Bréb. ex Kütz.) Grun. in V. H.
*N. rhynchocephala Kütz.
*N. vulpina Kütz.
*Pinnularia braunii var. amphicephala (A. Mayer) Hust.
*P. viridis (Nitz.) Ehr.
Stauroneis acuta W. Sm.
*S. phoenicenteron f. gracilis (Ehr.) Hust.

Gomphonemaceae

Gomphonema acuminatum Ehr.
*G. angustatum (Kütz.) Rabh.
*G. bohemicum Reichelt & Fricke
*G. parvulum (Kütz.) Kütz.
*G. sphaerophorum Ehr.
G. truncatum Ehr.

Cymbellaceae

Amphora ovalis (Kütz.) Kütz. var. ovalis
*A. ovalis var. pediculus (Kütz.) V. H. ex DeT.
Cymbella cistula (Ehr.) Kirch. in Cohn
C. inaequalis (Ehr.) Rabh.
*C. mexicana (Ehr.) Cl.
C. minuta var. silesiaca (Bleisch ex Rabh.) Reim. in Patr. & Reim.
C. naviculiformis Auersw. ex Heib.
*C. turgida Greg.

Epithemiaceae

*Epithemia adnata var. saxonica (Kütz.) Patr. in Patr. & Reim.
E. turgida (Ehr.) Kütz.
*Rhopalodia gibba (Ehr.) O. Müll.

Nitzschiaceae

*Nitzschia acicularis (Kütz.) W. Sm.
*N. acuta Hantz. ex Grun. in Cl. & Grun.
*N. amphibia Grun.
N. palea (Kütz.) W. Sm.
*N. sublinearis Hust.
*N. vermicularis (Kütz.) Grun.

Surirellaceae

Cymatopleura solea (Bréb. & Godey) W. Sm.
Surirella linearis var. constricta (Ehr.) Grun.

The checklist contains 78 entities, 58 of which are new records for Vilas County and for the entire northeastern lake district. Combining the present list with that of Conger (1939) we now have 143 diatom taxa reported from this region. If we consider, however, that the northeastern lake district contains 34% of all the lakes in 10% of the state's area (Frey, 1963), it would be hard to believe that the list is anywhere near completion. Hundreds of soft-water lakes, hard-water lakes, bogs, ponds, and streams occur in this region, many of which are still unexplored.

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REVIEWS

COMMON PLANTS BOTANICAL AND COLLOQUIAL NOMENCLATURE. By John J. Cunningham & Rosalie J. Côté. Garland Publishing, New York, 1977. 120 pp. $15.00.

The major parts of this book are a 40-page "Index of Botanical Nomenclature," listing about 2000 common names and an equivalent scientific name for each, and a 40-page section on "The History and Folklore of the Common Names of Selected Plants." The 32 books from which *Common Plants* was compiled are listed in the bibliography.

History might have been different had this book been available to Gutenberg. Realizing that such a shoddy opus could come from a printing press, he probably would have invented something else. Some might opine that the work is not worth space in a review, but to ignore it is to give it tacit approval. Publishers should not be able to commit dastardly deeds with impunity.

Common Plants is dismally researched and incredibly carelessly produced. A sham, it has so many errors that the mind is boggled.

The book is printed offset from typed pages. The myriad mis-spellings suggest that the typist was probably blind. Just for laughs, let's note some of the ill-treated words. Among many mis-spelled generic names are the following (see if *you* can figure out what each is supposed to be): *Barberis, Boxbax, Caboba, Canya, Ceris, Cicus, Circuta, Clemantis, Convulvus, Dionacea, Epibolium, Latuca, Nicotinia, Ocium, Optunia, Pellacea, Piguicula*, and *Verbana.* Many specific epithets are twisted, sometimes beyond recognition. One of these is *anera*–indecipherable if it were not coupled with *Juglans* and "walnut (white)" and is thus revealed as *cinerea* in disguise. Another is *puloguin.* A kind of antarctic bird? No, merely a contorted "*pulegium*" of *Mentha.* Finally, as a bonus are some double deformations, binomials with *both* words mis-spelled, e.g., *Aristolocia elegens, Artemesia aborantum, Chicorium endivium, Cimifuga foetidae, Pedicularia greenlandis,* and *Simbucus ebullus. Coix lacryma* var. *joli* [*Coix lacryma-jobi*] is a special case.

Even common names do not escape mutilation. How easy it is to find gems like Dutchman's breetches, dwarf edler, salisfly (An insect? No, merely *Tragopyron* [sic] *porrifolius*), cottoneaster, butter bush [*Cephalanthus occidentalis*!], canterberry bells, red ceder, flowering bush [*Butomus umbellatus*!], hornbean, macademia nut, Manilla hemp, poinsetta, quilwort, Port Oxford ceder, ruttabaga, taragon, and tumeric.

Some of the book's scientific names seem newly created for the occasion. Take, as examples, *Allium dracontium, Mentha fistulosa, Mentha didyma, Oxytropis rigidior,* and *Thlaspi bursa-pastoris.*

Cunningham and Côté were not even careful enough to discover that broomcorn is not *Panicum millaceum* [sic], that chick pea is not *Vicia americana,* that horse chestnut is not *Aesculus glabra,* that licorice is not *Glycyrrhiza lepidota,* and that vetch is not *Vinca* spp.

Understanding of intricacies of botanical nomenclature is not one of the authors' strong points. An early hint of trouble appears on p. 11 where, with regard to spelling in the book's lists, we read that "the variable 'ii' ending of Latin species [sic] epithets appears as 'i' in every case." Incorrect scientific names litter the book. The abbreviation "spp." is misused in "*Comptonia* spp." and "*Epifagus* spp."–these are monotypic genera. Compare these with "*Pistia* sp."–also monotypic (why not then *Pistia stratiotes*?).

Many scientific names given as equivalents to common names are too restricted. For example, aloe is more than just *Agave virginica;* bulrush, more than *Scirpus validus*; burdock, more than *Arctium lappa*; knotweed, more than *Polygonum glaucum*; crabgrass, more than *Digitaria decumbens*; grape, more than *Vitus [sic] vinifera*; yam, more than *Dioscorea batatas;* and heather, more than *Erica* spp. In contrast, some scientific-name equivalents are not restricted enough. Butterfly weed, for example, is less than *Asclepias* spp.; canary bird vine, less than *Tropaeolum* spp.; and madder, less than Rubiaceae.

Among tidbits of misinformation in the section on history and folklore are that flowers of *Trillium erectum* "smell much like decaying meat and attract flies that act as agents of seed dispersal"; that *Asclepias syriaca* "is actually a native of the Orient"; that stinkhorn is *Phalleles* [sic] spp. (bowdlerization?); and that *Cnidoscolus stimulosa* [sic] has "stringing hairs" (better, perhaps, than singing hairs).

Then there are the many common names that really *ought* to appear in the book. Perhaps it is fortunate for them that they were omitted.

To close this recital of errors, *Bromus brazilaeformis*—the brome grass shaped like a South American country—is a good choice. What a marvelous transmogrification of *Bromus brizaeformis*!

The authors of this worthless work are identified by their names only; no professional address or affiliation is revealed. Having descended into seldom plumbed depths of shabbiness, they and the publishers owe, to those unfortunates who have bought this terrible tome, an apology for their crime against botany. All copies of *Common Plants* should be recalled, shredded, and composted. Thus would their cellulose be redeemed.

John W. Thieret

TOXIC AND HALLUCINOGENIC MUSHROOM POISONING: A HANDBOOK FOR PHYSICIANS AND MUSHROOM HUNTERS. By Gary Lincoff & D. H. Mitchel. Van Nostrand Reinhold Co., New York. 1977. 267 pp. Hardbound: $16.95.

Every year cases of mushroom poisoning occur in this country. Frequently the attending physician seeks advice from local (or distant) professional mycologists, or knowledgeable non-professionals, on mushroom identification and mushroom poisoning. The mycologist tries to identify the mushroom and inform the physician about what to expect in that type of poisoning—leaving the physician to determine a course of treatment. Lincoff and Mitchel have provided a reference not only for those who identify mushrooms but also for the physician who, with little experience in the area, must act quickly to provide effective treatment. The authors discuss the seven principal types of mushroom poisoning known to occur in North America: cyclopeptide, monomethylhydrazine, coprine, muscarine, ibotenic acid-muscimol, psilocybin-psilocin poisonings, and gastrointestinal irritants. For each type of poisoning they discuss its incidence, severity, toxicology, and treatment. They also provide a discussion supplemented by lists of mushrooms suspected or proven to contain each type of toxin with references to pertinent literature. Drawings of one or more species in each group are presented, and 28 color photographs also provide help in identifying a number of the species mentioned in the text. A chapter devoted to the diagnosis and treatment of mushroom poisoning includes suggestions as to how physicians might proceed when faced with such a case and how to determine appropriate treatment. It gives considerable detail on the pharmacology, symptoms, laboratory studies, toxicity, and treatment of each type of poison. A series of appendices round out the book with information on field guides, technical descriptions of illustrated species, chemical structures of various toxins, and a sample of the "Mushroom Poisoning Contact Form." A list, by state, of groups and institutions which can provide help in identifying mushrooms and advice on poisonings and the addresses of American and Canadian centers for reporting cases of mushroom poisoning are also included, as is an "Abstract of toxins, mushrooms, symptoms and treatment" in chart form.

This book will fill the gap between the generalized discussions of mushroom poisoning in popular guides and the technical literature of toxicology, biochemistry, and case histories and will be welcomed alike by the serious consumer of wild mushrooms and the professional mycologist. For physicians who need ready access to the literature on the treatment of mushroom poisonings, this will undoubtedly become a valued reference.

—Nancy Weber

The March issue (Vol. 17, No. 2) was mailed May 26, 1978.

CONTENTS

A Scanning Electron Microscopic Study of the Trichomes in Brasenia schreberi
Kenneth D. Laser 83

Vegetational Patterns on the Tittabawasee Floodplain at the Goetz Grove Nature Center, Saginaw, Michigan
Richard H. Wheeler and Ronald O. Kapp 91

Eastern Hemlock Germination Influenced by Light, Germination Media, and Moisture Content
Michael S. Coffmann 99

Bruce Fink's Lichen Collections in Minnesota
Clifford M. Wetmore 103

Investigations on the Freshwater Algae of Wisconsin
I. Plankton Diatoms from High Lake (Vilas County)
Louis L. Lipsey, Jr. and Mason G. Fenwick 113

Reviews 118

On the cover: Part of Minnesota Botanical Survey party at Rock Harbor Lighthouse, Isle Royale, Michigan; photo by C. J. Hibbard, 1902

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VASCULAR FLORA OF THE RAVINES ALONG LAKE MICHIGAN IN LAKE COUNTY, ILLINOIS

Robbin C. Moran

Department of Botany, Southern Illinois University, Carbondale, 62901

Along Lake Michigan between Waukegan and Evanston, Illinois, are a series of forested ravines that cut westward into 20-30 meter high bluffs of a glacial moraine. Some of the ravines are entrenched as far back as one mile from the shoreline. Surrounding the ravines is relatively flat forest land dominated by oaks. Adjacent to the lake the eroding clay bluffs are in most locations quite steep (Fig. 1). These upland woods, lake bluffs, and deep shaded ravines, cooled by breezes off Lake Michigan, provide the habitat for many noteworthy plants. Of special interest are plants with northern affinities. Two such plants, *Shepherdia canadensis* and *Equisetum scirpoides,* are known in Illinois only from the ravines. Other species typically northern in distribution but known from other Illinois locations occur near Lake Michigan in abundance.

This paper provides an annotated flora and description of the vegetation of the ravines, lake bluffs, and adjacent oak uplands. The area under

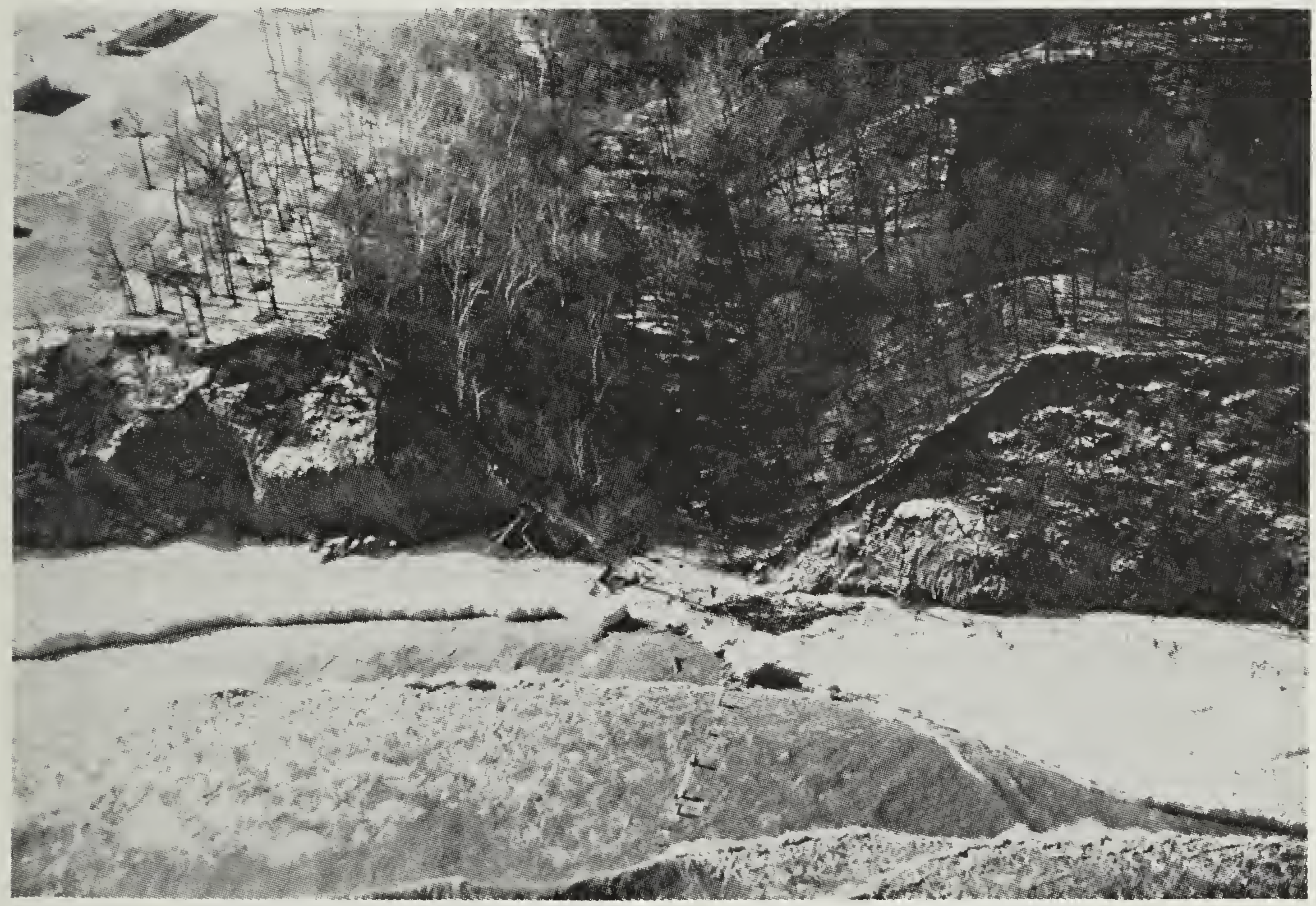

Fig. 1. A typical ravine mouth at Lake Forest. The white trunks of Paper Birch (*Betula papyrifera*) can be seen on the north-facing slope. Note the severe erosion of morainal bluffs. (Courtesy of the Illinois State Geological Survey).

consideration extends along the Lake Michigan shore from Waukegan 15 miles south to the Lake County–Cook County border. North of Waukegan and south of Evanston (in Cook County) is the flat lake plain of extinct Glacial Lake Chicago where morainal bluffs are not present.

Climatic data (Page, 1949) are available from a weather station at Waukegan, two miles north of the study area. Total average annual precipitation is 80.36 cm, with September, the wettest month, receiving an average of 10.26 cm. Total average snowfall is 72.4 cm annually, with the largest amount, 20.32 cm, in January. The average date of the last killing frost is April 28th; the average date of the first killing frost is October 13. Thus, there is an average of 168 frost-free days per year. Prevailing winds in the summer are east from Lake Michigan and from the northwest in winter. The average July temperature is 22.38°C, while the average January temperature is −4.11°C. The average July temperature is cooler than any other temperatures in the state due to the ameliorating effect of Lake Michigan.

Information on soils is taken from Paschke & Alexander (1970): The soil of ravine slopes is Hennepin loam that occurs on slopes of 15-60% and has a thin layer of topsoil with good internal drainage. Upland soils are predominantly Beecher and Morley silt loams. These soils have a topsoil with low organic matter and much clayey material on or near the surface. They also have seasonally high water tables, are subject to frost heave, and are slightly acidic. Wooded bluffs facing Lake Michigan usually have Hennepin loam soil. The soil of eroded bluffs is glacial till that is mostly comprised of clay.

The ravines were studied in the early 1900's primarily by H. C. Cowles (1901) and his students at the University of Chicago. Cowles discussed their vegetation in relation to vegetation occurring elsewhere in the vicinity of Chicago. Ullrich (1915) studied the relationship of evaporation and soil moisture to plant succession in a ravine. Schmoll (1919) described the vegetation of four habitat types and their successional tendencies. The papers of Cowles and Schmoll include many interesting photographs of undisturbed ravine and lake bluff vegetation.

The process of ravine formation by erosion was discussed by Cowles and will not be treated here. Nevertheless, note should be made of the importance of ravine slope erosion to plant life. In the spring, abundant moisture between clay particles in the till causes a downward slippage of large amounts of earth. Such slippage exposes new till as a microsite for succession. Annual plants of a weedy nature, such as *Erigeron annuus, Geum canadense,* and *Melilotus alba,* are the first to colonize. With time, more species occur on the eroded slopes, the older slopes usually gaining more "conservative" species. Well-drained decurrent ridges, left behind between former masses of till that have slumped to the ravine bottom, are habitat for such species as *Carex eburnea, C. pedunculata, Lathyrus ochroleucus,* and *Mitchella repens,* which prefer dry stabilized locations. Thus, as a short-term disturbance, natural erosion is important in maintaining diversity and giving some species their "place" in the community.

Today many ravines are degraded owing to disturbances—powerlines, pipelines, land fill, excess storm water runoff from subdivisions, introduction of exotic plants, and trampling. Slope erosion control practiced by developers and homeowners who have built expensive homes too close to the ravine edge is often destructive of vegetation. Only a few tracts of oak upland woods remain due to their desirability for homes. Only two ravines remain in a relatively undisturbed condition, one in T.43N, R.12E, NE¼ sec. 21, in the Village of Lake Bluff, the other in T.43N, R.12E, SE¼ sec. 3, in the City of Lake Forest, north of and adjacent to Fort Sheridan Army Base. Most collecting for this study was done in these two ravines. Also at Fort Sheridan, on the east-facing clay bluffs, there remains open prairie-like vegetation of the type described by Cowles and Schmoll.

The writer was unable to find 16 species (listed below) recorded by earlier botanists; some of them may have been extirpated from the ravines due to disturbances.

Aplectrum hyemale
Carex careyana
C. shortiana
Circaea alpina
Cypripedium reginae
Dryopteris intermedia
Equisetum scirpoides
E. variegatum
Habenaria hyperborea var. huronensis
Lycopodium porophilum
Myosotis virginica
Orchis spectabilis
Plantago cordata
Populus balsamifera
Sorbus americana
Thelypteris hexagonoptera

Ravine slopes. The mesic slopes are dominated primarily by *Acer saccharum, Quercus rubra,* and *Tilia americana* in varying abundance. Closer to Lake Michigan on north-facing slopes *Betula papyrifera* becomes important in many of the ravines. It is likely that in presettlement times *Pinus strobus* and *Thuja occidentalis* were important near the mouth of the ravines, but they are of little importance today. An early photograph of a ravine mouth and the lake (Pepoon, 1927) suggests their greater frequency, as do the original land survey records made in the late 1830's (Moran, 1978). Of special phytogeographic interest are the only known colonies in northern Illinois for *Fagus grandifolia,* on north-facing ravine slopes (Jensen, 1928). The largest colony of *Fagus grandifolia,* located in the City of Highland Park, appears to be doing quite well.

The most characteristic understory plant on the ravine slope is *Hamamelis virginiana.* Also common in the understory are *Amelanchier laevis, Cornus alternifolia,* and *Ostrya virginiana.* Essentially the same tree species occur at the bottom of the ravines as on the slopes, although *Populus deltoides* and several species of *Salix* are better represented there. Scattered throughout the length of the ravines, on the lower portion of the ravine slopes, are small areas where calcareous groundwater percolates out of glacial till. Seeps on the north-facing slopes are dominated by *Symplocarpus foetidus;* those on the south-facing slopes are dominated by *Carex stricta.* It was in one of these seeps that Hill (1905) found the "finest growth" of *Equisetum scirpoides.*

Ravine Crests. The ravine crest is a narrow zone extending back 3-7 meters from the ravine edge. It is distinguished from the upland woods because of its open character and unique assemblage of species. *Gaylussacia baccata, Hieracium scabrum, Hypoxis hirsuta, Pedicularis canadensis, Poa languida, Polygala senega, Sisyrinchium albidum, Trientalis borealis,* and *Vaccinium angustifolium* var. *laevifolium* are limited to the ravine crest. Others such as *Acer rubrum, Aralia nudicaulis, Diervilla lonicera, Krigia biflora, Lathyrus ochroleucus, Lonicera dioica, Maianthemum canadense* var. *interius,* and *Monotropa uniflora,* as well as many mosses and lichens, reach their greatest abundance in this zone.

Oak Upland Woods. The upland woods are dominated by *Quercus alba* and *Q. rubra.* Less common trees include *Q. ellipsoidalis, Q. bicolor,* and *Carya ovata.* By far the most common understory shrub is *Hamamelis virginiana.* The herbaceous layer is dominated by *Carex pensylvanica.* The upland woods are flatwoods with perched water tables in the spring resulting in many small ephemeral ponds. Species characteristic of the moist depressions are *Calamagrostis canadensis, Carex tribuloides, Cinna arundinacea, Quercus bicolor,* and *Thelypteris palustris* var. *pubescens.*

Lake Bluffs. Most of the clay bluffs facing Lake Michigan are wooded with *Acer saccharum, Fraxinus americana, Quercus alba, Q. rubra,* and *Tilia americana.* Open areas of stable clay bluffs may support prairie-like openings with many dry prairie forbs; however, prairie grasses are absent. A large portion of the bluffs are denuded owing to erosion by Lake Michigan. In the Village of Lake Bluff the bluffs have receded an average of 81 meters, or 267 feet, since 1872 (Berg & Collinson, 1976). Erosion has greatly decreased the numbers of typical lake bluff plants (Cowles, 1901; Schmoll, 1919), such as *Shepherdia canadensis* and *Populus balsamifera.* In the past, many bluffs were planted with *Robinia pseudo-acacia* to help prevent erosion.

Cowles presented an interesting discussion of plant succession on the lake bluffs and stated, "There can be almost no other habitat in our climate which imposes such severe conditions upon vegetation as an eroding clay bluff." The xeric character of the lake bluff results from exposure to wind, midday heat, winter cold, and unstable clay that is hard as rock in summer, yet wet in other seasons. Plants listed by Cowles as characteristic of the lake bluffs were *Aster laevis, Cornus stolonifera, Equisetum hyemale* var. *affine, Juniperus communis* var. *depressa, J. virginiana* var. *crebra, Melilotus alba, Ostrya virginiana, Pinus strobus, Populus balsamifera, P. tremuloides, Quercus ellipsoidalis, Q. rubra, Salix glaucophylloides* var. *glaucophylla,* and *Thuja occidentalis.* Apparently *Shepherdia canadensis,* now found in Illinois only in the Lake Michigan ravines, reached its greatest abundance along the lake bluffs (Cowles, 1901; Schmoll, 1919; Smith, 1912). Smith stated that a birch-conifer type of vegetation was characteristic of clay bluffs that had been undisturbed for many years. He also mentioned, "Frequently the foot of the cliff is fringed with lindens which together with the willows thrive in the moisture which seeps out upon the beach plain." Of significance here is a collection of

Pinus resinosa from the base of a clay bluff at Lake Forest made by R. A. Evers in 1955. The species is known from only one other Illinois location, along the Fox River in La Salle County.

The following catalogue includes 367 species of native and naturalized plants summarized (exclusive of hybrids and infraspecific taxa) as follows:

	Native	Introduced
Pteridophytes	15	0
Gymnosperms	5	1
Monocots	72	8
Dicots	222	42
	316	51

Almost all taxa listed were collected by the author from 1975 through 1977. However, several species are listed from literature citations or specimens deposited at the Illinois Natural History Survey (ILLIS), University of Illinois, Urbana (ILL), University of Wisconsin, Madison (WIS), and Field Museum of Natural History, Chicago (F). The writer's vouchers are deposited at the Morton Arboretum, Lisle, Illinois (MORT). The order of families and nomenclature is that of Mohlenbrock (1975). Genera and species have been arranged alphabetically. Species preceded by an asterisk are alien or introduced. Common names and the author's collection numbers are followed by a statement of habitats and relative abundance.

EQUISETACEAE (Horsetail Family)

Equisetum arvense L. Common Horsetail. 44. Common throughout, locally abundant at base of ravines.

E. fluviatile L. Water Horsetail. 441. Rare, bottom of ravines on moist soil.

E. hyemale L. var. affine (Engelm.) A. A. Eaton. Scouring Rush. 90. Occasional in bottom of ravines and on sandy soil at ravine mouths.

E. scirpoides Michx. Dwarf Scouring Rush. See Hill (1905) and Jones & Fuller (1955).

E. variegatum Schleich. Variegated Scouring Rush. See Hill (1905).

LYCOPODIACEAE (Clubmoss Family)

Lycopodium porophilum Lloyd & Underw. Cliff Clubmoss. Known only from an early collection by Vasey at Lake Forest (Swink, 1974).

OPHIOGLOSSACEAE (Adder's-tongue Family)

Botrychium virginianum (L.) Sw. Rattlesnake Fern. 235. Occasional throughout but most frequent in ravine bottoms.

OSMUNDACEAE (Royal Fern Family)

Osmunda claytoniana L. Interrupted Fern. 237, 452. Rare but found everywhere except on the lake bluffs.

POLYPODIACEAE (Polypody Family)

Adiantum pedatum L. Maidenhair Fern. 236. Common on ravine slopes.

Athyrium filix-femina (L.) Roth var. rubellum Gilb. Lady Fern. 407. Common throughout.

Dryopteris carthusiana (Villars) H. P. Fuchs. Spinulose Wood Fern. 232. Common in ravines and upland woods.

D. intermedia (Muhl.) Gray. Common Woodfern. Cited by Pepoon (1927).

Matteuccia struthiopteris (L.) Tardo. Ostrich Fern. 476. Occasional in ravine bottoms on moist soil.

Onoclea sensibilis L. Sensitive Fern. 236. Common in moist depressions of upland woods.

Pteridium aquilinum (L.) Kuhn var. latiusculum (Desv.) Underw. Bracken Fern. 311. Locally common in upland woods and along the ravine crests.

Thelypteris hexagonoptera (Michx.) Weatherby. Broad Beech Fern. Cited by Pepoon (1927).

T. palustris Schott var. pubescens (Laws.) Fern. Marsh Fern. 476. Moist areas in oak upland woods.

PINACEAE (Pine Family)

Pinus resinosa Ait. Red Pine. Collected by Robert A. Evers at the base of a clay bluff at Lake Forest in 1955 (Evers 47164, ILLS). Probably not present today because of erosion by Lake Michigan.

P. strobus L. White Pine. 91. Smith (1912) stated that this species commonly occurred along the upper portion of the lake bluff. Today it occurs sparingly near the lake.

*Tsuga canadensis (L.) Carr. Eastern Hemlock. 94. Two spontaneously occurring individuals were seen at the bottom of a ravine in Lake Bluff. Six large parent trees were planted on the uplands nearby.

CUPRESSACEAE (Cypress Family)

Juniperus communis L. var. depressa Pursh. Ground Juniper. 41, 58. Occasional on ravine slopes and crests, becoming common toward the lake. Described by early botanists (Cowles, 1901; Smith, 1912) as "characteristic" of the lake bluffs.

J. virginiana L. var. crebra Fern. Red Cedar. 59. On south-facing slopes near the ravine mouth; also on lake bluffs.

Thuja occidentalis L. Arbor Vitae. 98. Usually occurring close to Lake Michigan; locally common.

POACEAE (Grass Family)

Agrostis perennans (Walt.) Tuckerm. Upland Bent Grass. 462. Common along ravine crests and in upland woods.

*Anthoxanthum odoratum L. Sweet Vernal Grass. 246. Ravine crest.

Brachyelytrum erectum (Schreb.) Beauv. 404. Frequent on ravine slopes and bottoms of the ravines where it often forms dense stands.

Bromus purgans L. Brome Grass. 380, 459. Common throughout.

Calamagrostis canadensis (Michx.) Beauv. Bluejoint Grass. 525. Locally abundant in wet depressions of upland woods.

Cinna arundinacea L. Stout Wood Reed. 477. Common in moist habitats in upland woods.

Danthonia spicata (L.) Beauv. Poverty Oat Grass; Curly Grass. 372. Characteristic of the ravine crests.

Elymus canadensis L. Nodding Wild Rye. 450, 482. Occasional in upland woods and on lake bluffs.

E. hystrix L. Bottlebrush Grass. 369. Common throughout.

Glyceria striata (Lam.) Hitchc. Fowl Manna Grass. 310. Common on moist soil in ravine bottoms and upland woods.

Leersia virginica Willd. White Grass. 406. Common throughout.

Muhlenbergia mexicana (L.) Trin. Muhly. 457. Usually found near ravine mouths in sandy soil.

M. tenuiflora (Willd.) BSP. Slender Muhly. 431, 555. Rare on ravine slopes.

Oryzopsis racemosa (J. E. Smith) Ricker. Rice Grass. 394, 432. Occasional on ravine slopes and crests.

Panicum lanuginosum Ell. var. implicatum (Scribn.) Fern. Panic Grass. 376. Common in upland woods, along trails, and on lake bluffs.

P. latifolium L. Broad-leaved Panic Grass. 323. Occasional throughout.

Poa alsodes Gray. Woodland Bluegrass. 211, 429. Frequent on upland woods and ravine crests.

P. languida Hitchc. Woodland Bluegrass. 247, 430. Characteristic of ravine crests; common.

*P. pratensis L. Kentucky Bluegrass. 248. Locally common in open areas.

CYPERACEAE (Sedge Family)

Carex albursina Sheldon. 284. Occasional throughout.
C. blanda Dew. 22, 233. Common throughout the ravines and upland woods.
C. brevior (Dew.) Mack. 266. Moist depressions in upland woods.
C. careyana Torr. Cited by Pepoon (1927).
C. cephalophora Muhl. 50, 263. Common in oak upland woods.
C. convoluta Mack. 255. Common in ravines and upland woods.
C. eburnea Boott. 48, 51. Common on dry soils of ravine crests, uplands, and on exposed clay near the lake.
C. hirsutella Mack. 281. Occasional in oak upland woods.
C. hystricina Muhl. 261. Abundant in south-facing seeps.
C. lacustris Willd. 286. Common in south-facing seeps.
C. laevivaginata (Kükenth.) Mack. 288. Rare; in a south-facing seepage area.
C. muskingumensis Schk. 528. Wet depressions in upland woods; common.
C. pedunculata Muhl. 26. Locally abundant on stable, dry ravine slopes.
C. pensylvanica Lam. 23. Common throughout but most abundant on uplands where it forms dense sods covering large areas.
C. shortiana Dew. Cited by Pepoon (1927) as occurring near the "heads" of the ravines running into the lake.
C. sparganioides Muhl. 225. Occasional on oak uplands.
C. squarrosa L. 397. Occasional on oak uplands.
C. stipata Muhl. 262. In south-facing seeps and moist depressions in oak upland woods.
C. stricta Lam. 375. Dominant sedge in south-facing seeps.
C. tenera Dew. 275. Occasional in oak upland woods.
C. tribuloides Wahlenb. 398. Wet depressions in oak upland woods; frequent.
C. vulpinoidea Michx. 274. Occasional in oak upland woods, especially near wet places.
Scirpus atrovirens Willd. 373. Moist soils in ravine bottoms.

ARACEAE (Arum Family)

Arisaema dracontium (L.) Schott. Green Dragon. 169. Occasional throughout.
A. triphyllum (L.) Schott. Jack-in-the-Pulpit. 29. Common in ravines and oak upland woods.
Symplocarpus foetidus (L.) Nutt. Skunk Cabbage. 33. Characteristic of seeps on north-facing slopes where it usually forms extensive colonies.

JUNCACEAE (Rush Family)

Juncus tenuis Willd. Path Rush. 371. Common in paths in the oak upland woods.
Luzula multiflora (Retz.) Lejeune. Wood Rush. 264. Common on ravine crests.

LILIACEAE (Lily Family)

Allium canadense L. Wild Onion. 234. Common throughout.
A. tricoccum Ait. var. tricoccum. Wild Leek; Ramp. 198. Rare in ravines. Var. burdickii Hanes. 34. Common throughout.
*Asparagus officinalis L. Asparagus. 368. Rare in open areas of oak woods.
*Convallaria majalis L. Lily-of-the-Valley. 126. Usually near upland gardens.
Erythronium albidum Nutt. White Dog-tooth Violet; White Trout Lily. 35, 60. Abundant throughout; much more common than the next.
E. americanum Ker. Yellow Dog-tooth Violet; Yellow Trout Lily. 36, 61, 62. Locally abundant in several ravines.
*Hemerocallis fulva L. Orange Day Lily. 616. Occasional on upland woods.
Hypoxis hirsuta (L.) Coville. Yellow Star Grass. 221. Occasional on ravine crests.
Lilium michiganense Farw. Turk's-cap Lily. 356. Common in seeps; occasional in moist depressions on the uplands.
Maianthemum canadense Desf. var. interius Fern. False Lily-of-the-Valley. 63, 184. Common throughout.

*Narcissus pseudo-narcissus L. Daffodil. 121. Escaped from gardens on urbanized uplands; infrequent.

Polygonatum commutatum (Schult.) A. Dietr. Solomon's Seal. 107. Common on ravine slopes.

P. pubescens (Willd.) Pursh. Small Solomon's Seal. 150, 449. More common than the preceding; on ravine slopes and crests.

*Scilla sibirica Andr. Squill. Known from a ravine in Highland Park (Robertson 1047, ILLS).

Smilacina racemosa (L.) Desf. False Solomon's Seal. 183, 518. Common throughout.

S. stellata (L.) Desf. Small False Solomon's Seal. 183, 518. Common in south-facing seeps.

Trillium grandiflorum (Michx.) Salisb. Large White Trillium. 38. Common throughout the ravines and upland woods.

T. recurvatum Beck. Red Trillium; Wake Robin. 39. Common throughout the ravines and upland woods. This writer has twice seen the yellow form (f. luteum) in the upland woods.

Uvularia grandiflora Sm. Yellow Bellwort. 40. Common in ravines.

SMILACACEAE (Cat-brier Family)

Smilax ecirrhata (Engelm.) S. Wats. Carrion Flower. 120. Common in ravines.

S. lasioneuron Hook. Carrion Flower. 257. Common in ravines.

DIOSCOREACEAE (Yam Family)

Dioscorea villosa L. Wild Yam. 269, 401. Occasional throughout.

IRIDACEAE (Iris Family)

Iris shrevei Small. Wild Blue Iris. 529. Occasional in seeps.

Sisyrinchium albidum Raf. Blue-eyed Grass. 249. Rare along ravine crests.

ORCHIDACEAE (Orchid Family)

Aplectrum hyemale (Muhl.) Torr. Putty-root Orchid. Cited by Pepoon (1927) as occurring with Thuja occidentalis at a ravine in Highland Park.

Cypripedium calceolus L. var. pubescens (Willd.) Correll. Yellow Lady's-slipper Orchid. 151. Rare on ravine slopes.

C. reginae Walt. Showy Lady's-slipper Orchid. Known from a herbarium specimen at ILL.–"Edges of ravines, Lakeside, 18 June 1890 " (no collector's name).

*Epipactis helleborine (L.) Crantz. Helleborine. 400. Common throughout.

Goodyera pubescens (Willd.) R. Br. Rattlesnake Plantain Orchid. Seen once. Collected at Lake Forest by Harper, 15 September 1893 (WIS).

Habenaria hookeri Torr. Hooker's Orchid. From a ravine at Lake Forest, Harper 1890 (WIS).

H. hyperborea (L.) R. Br. var. huronensis (Nutt.) Farw. Green Orchid. Moist slope of a ravine at Lake Bluff, E. J. Hill, 26 June 1908 (ILL). Probably collected in a south-facing seep.

H. viridis (L.) R. Br. var. bracteata (Muhl.) Gray. Bracted Green Orchid. Seen once but not collected, on the fresh clay surface of a recently eroded ravine slope. Collected by E. J. Hill at a ravine in Highland Park on 22 May 1880 (ILL).

Orchis spectabilis L. Showy Orchis. Collected by Babcock at a ravine in Glencoe, 5 June 1869 (F). Although Glencoe is in Cook County, it seems reasonable to assume that this species occurred in the Lake County ravines.

SALICACEAE (Willow Family)

Populus balsamifera L. Balsam Poplar. Cited by Cowles (1901), Schmoll (1919), and Smith (1912) as occurring characteristically along lake bluffs. Probably now extirpated due to extensive bluff erosion by Lake Michigan.

P. deltoides Marsh. Cottonwood. 241. Common at bottoms of ravines.

P. grandidentata Michx. Large-toothed Aspen. 530. Occasional on ravine slopes.

P. tremuloides Michx. Quaking Aspen. 242. Open areas in oak upland woods and lake bluffs.

Salix amygdaloides Anderss. Peach-leaved Willow. 216. Occasional at bottom of ravines.

S. discolor Muhl. Pussy Willow. 27. Rare; wet depressions in oak upland woods.

S. glaucophylloides Fern. var. glaucophylla (Bebb) Schneid. Blue-leaf Willow. 45. Occasional near lake.

S. interior Rowlee f. wheeleri (Rowlee) Rouleau. Sandbar Willow. 397. Occasional in ravine bottom.

S. lucida Muhl. Shining Willow. 504. Rare, ravine bottom.

S. sericea Marsh. Silky Willow. 28. Moist, open areas in oak upland woods. The voucher specimen shows affinities to S. subsericea (Anderss.) Schneid.

S. syrticola Fern. Sand-dune Willow. Cited by Schmoll (1919) as occurring on the lake bluffs. Probably no longer present due to erosion from Lake Michigan.

JUGLANDACEAE (Walnut Family)

Carya ovata (Mill.) K. Koch. Shagbark Hickory. 312. Common on uplands.

Juglans cinerea L. Butternut. 313. Occasional in ravines.

BETULACEAE (Birch Family)

Betula lutea Michx. f. Yellow Birch. Known from a collection at the base of a clay bluff, Lake Forest (Evers 47170, ILLS).

B. papyrifera Marsh. Paper Birch. 95, 234. Always on north-facing ravine slopes; more frequent closer to Lake Michigan. Earlier botanists reported this species as characteristic of stabilized lake bluffs (Cowles, 1901; Schmoll, 1919).

Carpinus caroliniana Walt. var. virginiana (Marsh.) Fern. Blue Beech. 214, 447. Common throughout.

Corylus americana Walt. Hazelnut. 282. In open places on ravine crests and lake bluffs.

Ostrya virginiana (Mill.) K. Koch. Hop Hornbeam. 46, 175. Common throughout.

FAGACEAE (Beech Family)

Fagus grandifolia Ehrh. Beech. 210, 489. On north-facing ravine slopes. Known from several ravines, but the two best colonies are those described by Jensen (1928).

Quercus alba L. White Oak. 222. One of the dominant upland trees.

Q. bicolor Willd. Swamp White Oak. 408. Common around moist depressions in upland woods.

Q. ellipsoidalis E. J. Hill. Hill's Oak. 238. Common on upland woods and lake bluffs.

Q. macrocarpa Michx. Bur Oak. 531. Occasional on uplands.

Q. rubra L. Red Oak. 239. One of the dominant trees in the uplands; also on mesic ravine slopes.

ULMACEAE (Elm Family)

Ulmus americana L. American Elm. Cited by Schmoll (1919) and Cowles (1901) as occurring in uplands and ravines. Not seen; it appears that Dutch Elm Disease has taken its toll.

U. rubra Muhl. Slippery Elm; Red Elm. 543. Occasional throughout.

MORACEAE (Mulberry Family)

*Morus alba L. White Mulberry. 215. Rare, but throughout.

URTICACEAE (Nettle Family)

Pilea pumila (L.) Gray. Clearweed. 444. Common in moist shaded ravine bottoms.

SANTALACEAE (Sandalwood Family)

Comandra richardsiana Fern. False Toadflax. 181. Frequent along ravine crests.

POLYGONACEAE (Buckwheat Family)

*Polygonum cespitosum Blume var. longisetum (DeBruyun) Steward. Creeping Smartweed. 485. Locally abundant in disturbed ravine beds.

*P. cuspidatum Sieb. & Zucc. Mexican Bamboo. Disturbed ravine bed in Highland Park (Robertson 1153, ILLS).

P. virginianum L. Virginia Knotweed. 415. Abundant in oak upland woods.

*Rumex crispus L. Curly Dock. 243. Occasional in open, disturbed ravine beds and upland woods.

*R. obtusifolius L. Bitter Dock. 374, 381. Occasional throughout.

CHENOPODIACEAE (Goosefoot Family)

*Chenopodium album L. Lamb's Quarters. 532. Local in disturbed areas.

CARYOPHYLLACEAE (Pink Family)

Arenaria lateriflora L. Sandwort. 623. Occasional in oak upland woods.

Silene stellata (L.) Ait. f. Starry Champion. 542. Occasional in oak upland woods.

RANUNCULACEAE (Buttercup Family)

Actaea pachypoda Ell. Doll's-eyes. 152. Common in ravines.

A. rubra (Ait.) Willd. Red Baneberry. 132. Occasional in ravines.

Anemone quinquefolia L. var. interior Fern. Wood Anemone. 88. Common throughout ravines and oak upland woods.

A. virginiana L. Tall Anemone. 278. Common on south-facing slopes, oak upland woods, and lake bluffs.

Anemonella thalictroides (L.) Spach. Rue Anemone. 30. Common in upland woods and on ravine crests.

Aquilegia canadensis L. Columbine. Ravine slope at Highland Park (Robertson 1127, ILLS).

Caltha palustris L. Marsh Marigold. 52. In seeps and moist uplands.

Hepatica nobilis Schreb. var. acuta (Pursh) Steyerm. Sharp-lobed Hepatica. 31, 53. Abundant in ravines.

Ranunculus abortivus L. Small-flowered Crowfoot. 119. Common throughout.

*R. acris L. Tall Buttercup. 54. In open disturbed areas; local.

R. fascicularis Muhl. Early Buttercup. 134. Occasional throughout.

R. recurvatus Poir. 533. Rare on open ravine crests.

R. septentrionalis Poir. Swamp Buttercup. 55. Common throughout.

Sorbus americana Marsh. Mountain Ash. Cited by Pepoon (1927).

Thalictrum dasycarpum Fisch & Lall. Purple Meadow Rue. 31, 362.

T. dioicum L. Early Meadow Rue. 56, 101. Common in ravines and upland woods.

BERBERIDACEAE (Barberry Family)

*Berberis thunbergii DC. Japanese Barberry. 128. Occasional throughout.

*B. vulgaris L. Common Barberry. 314. Only one individual found on a dry, sunny ravine crest.

Caulophyllum thalictroides (L.) Michx. Blue Cohosh. Known from a ravine in Highland Park (Robertson 1035, 1328, ILLS).

Podophyllum peltatum L. Mayapple. 230. Occasional throughout.

MENISPERMACEAE (Moonseed Family)

Menispermum canadense L. Moonseed. Ravine bottom, Highland Park. (Robertson 1298, ILLS).

PAPAVERACEAE (Poppy Family)

Sanguinaria canadensis L. Bloodroot. 125. Frequent in ravines.

CRUCIFERAE (Mustard Family)

*Alliaria officinalis Andrz. Garlic Mustard. 113. Abundant in disturbed ravines.

Arabis laevigata (Muhl.) Poir. Smooth Rock Cress. 185. Common throughout.

Cardamine bulbosa (Schreb.) BSP. Spring Cress. 617. Occasional in moist habitats in upland woods.

C. douglassii (Torr.) Britt. Purple Cress. 57. Common in ravines.

C. pensylvanica Muhl. Small-flowered Bitter Cress. 187. Common throughout, especially near paths in oak upland woods.

Dentaria laciniata Muhl. Toothwort. 43. Common in ravines.

*Hesperis matronalis L. Rocket. 196. Infrequent in ravine beds.

SAXIFRAGACEAE (Saxifrage Family)

Mitella diphylla L. Bishop's-cap. 134. Common in ravines.

Penthorum sedoides L. Ditch Stonecrop. 443, 484. Common in ravine beds and moist upland depressions.

*Philadelphus coronarius L. Sweet Mock Orange. 317. Occasional on ravine slopes, usually near gardens.

Ribes americanum Mill. Wild Black Currant. 217. Common throughout.

R. cynosbati L. Prickly Gooseberry. 19, 116. The most common Ribes; throughout.

R. missouriense Nutt. Missouri Gooseberry. 534. Rare, on ravine slopes.

*R. sativum (Reichenb.) Syme. Red Currant. 96. Only one individual seen, on sandy soil at ravine mouth.

HAMAMELIDACEAE (Witch-hazel Family)

Hamamelis virginiana L. Witch-hazel. 49, 122, 519. The most common understory shrub throughout.

ROSACEAE (Rose Family)

Agrimonia gryposepala Wallr. Tall Agrimony. 365. Common throughout.

Amelanchier humilis Wieg. Low Shadbush. Bluffs, north of Lake Bluff (Evers 42304, ILLS).

A. interior Nielsen. Shadbush. 569. Only one individual seen, on a ravine crest close to Lake Michigan.

A. laevis Wieg. Shadbush. 47, 105, 153. Common on north-facing ravine slopes.

Crataegus holmesiana Ashe. Hawthorn. 154. Occasional in oak upland woods.

C. mollis (Torr. & Gray) Scheele. Red Haw. Cited by Schmoll (1919) as occurring in the upland woods.

C. punctata Jacq. Dotted Thorn. Cited by Schmoll (1919) as occurring on the oak uplands.

Fragaria virginiana Duchesne. Wild Strawberry. 92, 170. Common throughout.

Geum canadense Jacq. White Avens. 272. Common in moist depressions of oak upland woods.

Malus coronaria (L.) Mill. Wild Sweet Crab Apple. Cited by Schmoll (1919) as occurring in the oak upland woods.

M. pumila Mill. Apple. 108. Rare, south-facing ravine slope.

Physocarpus opulifolius (L.) Maxim. Ninebark. 260. Infrequent in ravine beds.

Potentilla anserina L. Silverweed. 435. Occasional in sandy soil at ravine mouths.

*P. norvegica L. Rough Cinquefoil. 572. On disturbed uplands and eroding clay bluffs.

P. simplex Michx. Common Cinquefoil. 186. Frequent in oak upland forest and on stabilized lake bluffs.

Prunus americana Marsh. Wild Plum. 146. Occasional throughout.

P. nigra Ait. Canada Plum. Seen once but not collected. Cited by Schmoll (1919) as occurring on the oak uplands.

P. serotina Ehrh. Wild Black Cherry. 182. Occasional throughout.

P. virginiana L. Common Chokecherry. 20, 21, 117, 118. Common throughout. Some specimens key to f. deamii.

Rosa blanda Ait. Meadow Rose. Cited by Schmoll (1919) as occurring on the lake bluffs and oak uplands.

R. carolina L. Pasture Rose. 318. Occasional along ravine crests and on stable lake bluffs.
Rubus flagellaris Willd. Dewberry. 287. Occasional in oak uplands.
R. occidentalis L. Black Raspberry. 615. Occasional in upland woods.
R. odoratus L. Purple Flowering Raspberry. 427. Locally common in ravines. Some ravine populations are definitely garden escapes while others appear to be native.
R. pensylvanicus Poir. Blackberry. 258. Occasional in oak upland woods.
R. strigosus Michx. Red Raspberry. 308, 347. Common in ravine beds, rare in oak upland woods.

LEGUMINOSAE (Bean Family)
Amphicarpa bracteata (L.) Fern. var. comosa (L.) Fern. Hog Peanut. 472. Occasional throughout.
Apios americana Medic. Groundnut. 353. Common in ravine beds.
Desmodium canadense (L.) DC. Showy Tick Trefoil. 392. Rare in uplands, common on stabilized lake bluffs.
D. glutinosum (Muhl.) Wood. Pointed Tick Trefoil. 359. Frequent in ravines.
Lathyrus ochroleucus Hook. Pale Vetchling. 176, 228. Common along ravine crests.
L. venosus Muhl. var. intonsus Butt. & St. John. Veiny Pea. 245. Occasional along ravine crests.
*Medicago lupulina L. Black Medick. 360. Infrequent in ravine bottoms.
*Melilotus alba Desr. White Sweet Clover. 422. Common on areas of eroding clay bluffs and disturbed uplands.
*Robinia pseudo-acacia L. Black Locust. 320. Locally common in all habitats. Planted for erosion control along lake.

OXALIDACEAE (Wood Sorrel Family)
*Oxalis stricta L. Yellow Wood Sorrel. 68. Occasional throughout.

GERANIACEAE (Geranium Family)
Geranium maculatum L. Wild Geranium. 123. Common throughout.

POLYGALACEAE (Milkwort Family)
Polygala senega L. Seneca Snakeroot. 195 Infrequent on ravine crests.

EUPHORBIACEAE (Spurge Family)
Euphorbia corollata L. Flowering Spurge. 315. Common on lake bluffs.

LIMNANTHACEAE (False Mermaid Family)
Floerkea proserpinacoides Willd. False Mermaid. 138. Rare in oak upland woods.

ANACARDIACEAE (Cashew Family)
Rhus glabra L. Smooth Sumac. 535. Along lake bluffs and in sandy soil at ravine mouths.
R. typhina L. Staghorn Sumac. 363. Common throughout.
Toxicodendron radicans (L.) Kuntze. Poison Ivy. 378. Common throughout.

CELASTRACEAE (Staff-tree Family)
*Celastrus orbiculatus Thunb. Round-leaved Bittersweet. 218. Locally common in sandy soil at ravine mouths.
C. scandens L. Bittersweet. 354. Occasional throughout.
*Euonymus alatus (Thunb.) Sieb. Winged Euonymus. 99. Occasional throughout.
E. atropurpureus Jacq. Wahoo. Cited by Schmoll (1919) as occurring in ravines and oak upland woods.

ACERACEAE (Maple Family)
Acer negundo L. Boxelder. 220. Occasional in ravine beds.

*A. platanoides L. Norway Maple. 93. Infrequent in ravines.

A. rubrum L. Red Maple. 179. Locally common on uplands and north-facing ravine slopes close to Lake Michigan.

A. saccharinum L. Silver Maple. 547. Occasional along the lake bluffs on moist clays.

A. saccharum Marsh. Sugar Maple. 188, 223. One of the dominant trees of ravine slopes. Some individuals have A. nigrum-like characteristics.

HIPPOCASTANACEAE (Horse Chestnut Family)

Aesculus glabra Willd. Ohio Buckeye. 592. Only one small sapling found.

*A. hippocastanum L. Horse Chestnut. 102. Rare, ravine slopes.

BALSAMINACEAE (Touch-me-not Family)

Impatiens biflora Walt. Spotted Touch-me-not. 357. Common throughout.

RHAMNACEAE (Buckthorn Family)

Ceanothus americanus L. New Jersey Tea. 536. Occasional on stabilized lake bluffs.

*Rhamnus cathartica L. Common Buckthorn. 155. Occasional throughout, sometimes abundant in moist upland depressions.

*R. frangula L. Glossy Buckthorn. 227. Occasional throughout.

VITACEAE (Grape Family)

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper. 252. Frequent throughout.

Vitis aestivalis Michx. var. argentifolia (Munson) Fern. Silver-leaved Grape. 285, 566. Locally abundant in open areas of oak upland woods.

V. riparia Michx. Riverbank Grape. 240, 516. Occasional throughout.

TILIACEAE (Linden Family)

Tilia americana L. Basswood. 131. One of the dominant trees of mesic ravine slopes.

VIOLACEAE (Violet Family)

Viola conspersa Reichenb. Dog Violet. 256. Common along ravine crests; infrequent in oak upland woods.

V. nephrophylla Greene. Northern Blue Violet. 148. Occasional throughout.

V. pratincola Greene. Common Blue Violet. 65. Common throughout.

V. pubescens Ait. var. pubescens. Downy Yellow Violet. 178, 180. Common in ravines and oak upland forest. Some individuals key to var. peckii House. Var. eriocarpa (Schwein) Russell. Smooth Yellow Violet. 133. Common throughout, often with the typical variety.

V. sororia Willd. Woolly Blue Violet. 25, 147. The most common violet; throughout.

ELAEAGNACEAE (Oleaster Family)

Shepherdia canadensis (L.) Nutt. Canadian Buffalo-berry. 66. Rare; close to Lake Michigan in dry, open places. Most of its original lake bluff habitat has been destroyed by erosion.

ONAGRACEAE (Evening Primrose Family)

Circaea alpina L. Small Enchanter's Nightshade. Collected on the moist bank of a shady ravine (Hill 442, in 1908, ILL).

C. quadrisulcata (Maxim.) Franch. & Sav. var. canadensis (L.) Hara. Enchanter's Nightshade. 349. Common throughout.

Epilobium adenocaulon Haussk. Northern Willow Herb. 448. Common on moist soils throughout.

ARALIACEAE (Ginseng Family)

Aralia nudicaulis L. Wild Sarsaparilla. 103. Common throughout.

A. racemosa L. American Spikenard. 367. Occasional in ravines.

UMBELLIFERAE (Carrot Family)

*Aegopodium podagraria L. Goutweed. 273. A troublesome species in several ravines, forming dense colonies in moist soil of ravine bottoms.

Cryptotaenia canadensis (L.) DC. Honewort. 270. Occasional throughout.

*Daucus carota L. Wild Carrot; Queen Anne's Lace. 69. Locally common on disturbed uplands and on clay soils of lake bluffs.

Heracleum maximum Bartr. Cow Parsnip. 325. Occasional in ravines.

Osmorhiza claytonii (Michx.) Clarke. Sweet Cicely. 212. Common in ravines.

O. longistylis (Torr.) DC. Anise Root. 213. Common in ravines.

Oxypolis rigidior (L.) Coulter & Rose. Cowbane. 521. Rare; in moist depressions of the oak upland woods.

Sanicula gregaria Bickn. Common Snakeroot. 219, 405. Locally abundant in ravines, sometimes forming dense colonies.

Taenidia integerrima (L.) Drude. Yellow Pimpernel. 104. Frequent in ravines.

Zizia aurea (L.) Kock. Golden Alexanders. 190. In moist soil of ravine beds and oak upland woods.

CORNACEAE (Dogwood Family)

Cornus alternifolia L. f. Alternate-leaved Dogwood. 194. Common in ravines, especially around edges of seeps.

C. obliqua Raf. Pale Dogwood. 18. Occasional in ravine bottoms.

C. racemosa Lam. Gray Dogwood. 277. Common on the uplands.

C. rugosa Lam. Round-leaved Dogwood. 124. Occasional in ravines and along ravine crests.

C. stolonifera Michx. Red Osier. 577. Cited by Cowles (1901) and Schmoll (1919) as characteristic of the lake bluffs.

ERICACEAE (Heath Family)

Gaylussacia baccata (Wang.) K. Koch. Black Huckleberry. 250. Found only along ravine crests where it is locally abundant.

Monotropa uniflora L. Indian Pipe. 361. Rare; restricted to ravine crests.

Pyrola elliptica Nutt. Shinleaf. 321. Occasional throughout.

Vaccinium angustifolium Ait. var. laevifolium House. Lowbush Blueberry. 537. Rare; along ravine crests.

PRIMULACEAE (Primrose Family)

Dodecatheon meadia L. Shooting Star. 115. Common in ravines and along sunny ravine crests.

Lysimachia ciliata L. Fringed Loosestrife. 364. Common throughout.

L. quadrifolia L. Whorled Loosestrife. 280. Common in the oak upland woods.

Trientalis borealis Raf. Star-flower. 177. One small colony seen on a shaded ravine crest near the lake.

OLEACEAE (Olive Family)

Fraxinus americana L. White Ash. 197. Common in ravines.

F. nigra Marsh. Black Ash. 266. Moist soil of ravine bottoms, upland woods, and seeps.

APOCYNACEAE (Dogbane Family)

Apocynum androsaemifolium L. Spreading Dogbane. 244. Occasional along ravine crests.

*Vinca minor L. Common Periwinkle; Myrtle. 175. Occasionally escaped on slopes near gardens.

ASCLEPIADACEAE (Milkweed Family)

Asclepias exaltata L. Poke Milkweed. 350. Occasional throughout.

A. purpurascens L. Purple Milkweed. 350. Infrequent in oak upland woods.

A. verticillata L. Horsetail Milkweed. 538. Common on eroding ravine slopes and lake bluffs.

CONVOLVULACEAE (Morning-glory Family)

Calystegia spithamaea (L.) Pursh. Dwarf Bindweed. 259. On south-facing ravine slopes and lake bluffs.

Cuscuta gronovii Willd. Dodder. Seen but not collected. Known from a collection at Highland Park (Robertson 1333, ILLS).

POLEMONIACEAE (Phlox Family)

Phlox divaricata L. ssp. laphamii (Wood) Wherry. Blue Phlox. 112. Common in ravines.

HYDROPHYLLACEAE (Waterleaf Family)

Hydrophyllum virginianum L. Virginia Waterleaf. 539. Rare in oak upland woods.

BORAGINACEAE (Borage Family)

*Mertensia virginica (L.) Pers. Bluebells. 106. Locally abundant. Ravine populations represent escapes from cultivation.

Myosotis virginica (L.) BSP. Scorpion Grass. Cited by Pepoon (1927).

VERBENACEAE (Vervain Family)

Verbena urticifolia L. White Vervain. 399. Common in oak uplands.

LABIATAE (Mint Family)

*Glechoma hederacea L. Ground Ivy; Creeping Charlie. 100. Local in sunny areas of moist soil; throughout.

Lycopus virginicus L. Bugle Weed. 494. Moist soils at bottom of ravines and seeps.

Mentha arvensis L. var. villosa (Benth.) S. R. Stewart. 568. Field Mint. Rare in seeps of south-facing slopes.

Monarda fistulosa L. Wild Bergamot. 393. In disturbed upland woods and on lake bluffs.

Prunella vulgaris L. var. lanceolata (Bart.) Fern. Self-heal. 370. Occasional in oak upland woods.

Scutellaria lateriflora L. Mad-dog Skullcap. 442. In seeps of south-facing slopes.

Stachys palustris L. var. homotricha Fern. Woundwort. 522. On moist soils of ravine bottoms.

S. tenuifolia Willd. var. hispida (Pursh.) Fern. Hairy Hedge Nettle. 417. Local in wet depressions of oak upland woods.

SOLANACEAE (Nightshade Family)

Solanum americanum Mill. Black Nightshade. 416. Occasional throughout.

*S. dulcamara L. Bittersweet Nightshade. 253. Locally abundant in disturbed areas; common throughout.

SCROPHULARIACEAE (Figwort Family)

Gerardia grandiflora Benth. var. pulchra (Pennell) Fern. Yellow False Foxglove. 451. Common along the ravine crests and in oak upland woods.

Pedicularis canadensis L. Lousewort. 17, 226. Common along ravine crests.

*Veronica serpyllifolia L. Thyme-leaved Speedwell. 135. Occasional on trails.

OROBANCHACEAE (Broomrape Family)

Conopholis americana (L.) Wallr. Cancer-root; Squaw-root. Seen once but not collected. Cited by Pepoon (1927).

Orobanche uniflora L. One-flowered Broomrape. 67. Rare in oak upland woods.

PLANTAGINACEAE (Plantain Family)

Plantago cordata Lam. Heartleaf Plantain. Collected by E. J. Hill in a "rivulet in a ravine" at Highland Park (ILL).

*P. major L. Common Plantain. 618. In paths in upland woods.

RUBIACEAE (Madder Family)

Cephalanthus occidentalis L. Buttonbush. 414. Rare in wet depressions of oak upland woods.

Galium aparine L. Goosegrass. 271. Occasional throughout.

G. concinnum Torr. & Gray. Shining Bedstraw. 322, 366. Common in oak upland woods.

G. tinctorium L. Stiff Bedstraw. 483. Occasional in wet depressions of oak upland woods.

Mitchella repens L. Partridge-berry. 193. Rare; on dry stabilized ravine slopes.

CAPRIFOLIACEAE (Honeysuckle Family)

Diervilla lonicera Mill. Bush Honeysuckle. 254. Common in oak upland woods and along ravine crests.

*Lonicera bella Zabel. 97. Common throughout.

L. dioica L. Red Honeysuckle. 192. Common throughout but reaching its greatest abundance along the ravine crest.

*L. japonica Thunb. Japanese Honeysuckle. 110. One small colony seen.

L. prolifera (Kirchn.) Rehd. Grape Honeysuckle. 268. Locally abundant throughout.

Sambucus canadensis L. var. canadensis. Elderberry. 352. Occasional throughout. Var. acutiloba Ellw. & Barry. 316. Only one individual seen in an oak upland woods at Lake Forest. New to the state.

Triosteum aurantiacum Bickn. Early Horse Gentian. 109. Infrequent throughout.

Viburnum acerifolium L. Maple-leaved Arrowood. 251. Common in ravines and on uplands.

*V. lantana L. Wayfaring Tree. 488. Rarely escaping.

V. lentago L. Nannyberry. 172, 189. Common throughout.

*V. opulus L. European High-bush Cranberry. 127, 231. Common in ravine bottoms.

V prunifolium L. Black Haw; Nannyberry. 149. Common throughout.

V. rafinesquianum Schultes. Downy Arrowwood. 191. Common throughout.

CAMPANULACEAE (Harebell Family)

Campanula americana L. American Bellflower. 413. Occasional throughout.

Lobelia cardinalis L. Cardinal-flower. 495. Local in stream beds.

L. siphilitica L. Blue Cardinal-flower. 445. Occasional throughout.

COMPOSITAE (Sunflower Family)

Ambrosia artemisiifolia L. Common Ragweed. 479. In disturbed open habitats.

A. trifida L. Giant Ragweed. 480. Infrequent throughout.

Antennaria plantaginifolia (L.) Hook. Pussytoes; Ladies'-tobacco. 42. Common along ravine crests.

*Arctium minus (Hill) Bernh. 493. Common Burdock. Infrequent in open areas.

Aster lateriflorus (L.) Britt. Side-flowered Aster. 511. Occasional throughout.

A. laevis L. Smooth Aster. 470. In sandy soil near ravine mouths and on lake bluffs.

A. macrophyllus L. Big-leaved Aster. 348. Common in oak upland woods and along ravine crests.

A. novae-angliae L. New England Aster. 512. Occasional on uplands and in south-facing seeps.

A. pilosus Willd. Hairy Aster. 514. Occasional throughout.

A. puniceus L. var. lucidulus Gray. Shiny Swamp Aster. 523. Local.

A. sagittifolius Wedem. ex Willd. Arrow-leaved Aster. 474, 475, 513. Common on uplands and lake bluffs. Var. drummondii (Lindl.) Shinners. 510. Common on uplands and lake bluffs. Often found growing with the typical variety.

Bidens frondosa L. Common Beggar-ticks. 492. Moist depressions in upland woods; occasional.
Cirsium altissimum (L.) Spreng. Tall Thistle. 402. South-facing ravine slopes, common.
*C. vulgare (Savi) Tenore. Bull Thistle. 473. In disturbed uplands and along lake bluffs.
Erechtites hieracifolia (L.) Raf. Fireweed. 570. Rare in oak upland woods.
Erigeron annuus (L.) Pers. Daisy Fleabane. 355. Occasional throughout.
E. philadelphicus L. Marsh Fleabane. 319. Common in ravine bottoms.
Eupatorium maculatum L. Spotted Joe-Pye-weed. 469. Common in moist soils throughout.
E. perfoliatum L. Common Boneset; Thoroughwort. 455. Occasional in ravine bottoms.
E. purpureum L. Purple Joe-Pye-weed. 493. Common in oak upland woods.
E. rugosum Houtt. White Snakeroot. 491. Frequent throughout.
*Galinsoga ciliata (Raf.) Blake. Peruvian Daisy; Quickweed. 437. In disturbed uplands and on lake bluffs.
Helenium autumnale L. Autumn Sneezeweed. 456. Common in ravine bottoms.
Helianthus strumosus L. Pale-leaved Sunflower. 395. Common on uplands and lake bluffs.
Hieracium scabrum Michx. Hairy Hawkweed. 453. Restricted to ravine crests where it is common.
*Inula helenium L. Elecampane. Known from a collection in a Highland Park ravine (Robertson 1031, ILLS).
Krigia biflora (Walt.) Blake. False Dandelion. 229. Common along ravine crests.
*Lapsana communis L. Nipplewort. Collected in an upland woods at Highland Park (Robertson 1172, ILLS).
*Petasites hybridus (L.) Gaertn., Mey. & Scherb. Sweet Coltsfoot; Butterbur. 271. Wet soils of ravine bottoms; rare.
Prenanthes alba L. White Lettuce; Rattlesnake Root. 454. Common on uplands.
Rudbeckia hirta L. Black-eyed Susan. 351. Occasional throughout, in many different habits.
R. laciniata L. Goldenglow. 446. Ravine bottoms in moist soil; occasional.
Senecio aureus L. Golden Ragwort; Squaw-weed. 267. In seeps on south-facing ravine slopes and in the upland woods in moist depressions.
Silphium terebinthinaceum Jacq. Prairie Dock. 471. Rare on sandy soil at ravine mouths, occasionally on lake bluffs.
Solidago canadensis L. Tall Goldenrod. 468, 524. Common in open upland situations and on lake bluffs.
S. flexicaulis L. Broadleaf Goldenrod. 467. Common throughout.
S. graminifolia (L.) Salisb. Grass-leaved Goldenrod. 436. Common on lake bluffs.
S. juncea Ait. Early Goldenrod. 396. Lake bluffs and upland woods.
S. nemoralis Ait. Field Goldenrod. 517. Common along ravine crests and on lake bluffs.
S. patula Muhl. Spreading Goldenrod. 466. Abundant in open south-facing seeps.
S. ulmifolia Muhl. Elm-leaved Goldenrod. 478, 520. Common throughout.
Taraxacum officinale Weber. Common Dandelion. 114. Occasional throughout.

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MORPHOLOGICAL VARIATION OF FAMILIES OF TREMBLING ASPEN IN SOUTHEASTERN MICHIGAN

Michele M. Farmer
Georgia Pacific Corporation
Northern California Division
90 West Redwood Avenue
Fort Bragg, California 49769

Burton V. Barnes
School of Natural Resources
University of Michigan
Ann Arbor, Michigan 48109

Hybrids between bigtooth aspen (*Populus grandidentata*) and trembling aspen (*P. tremuloides*) are not uncommon in disturbed areas of Michigan (Barnes, 1961; Wagner, 1970). They are much more prevalent in southeastern Lower Michigan than in northern Lower Michigan or in the Upper Peninsula. Because of their relatively high frequency in southeastern Michigan and the occurrence of a number of putative backcrosses or introgressants in that area, it has been suggested that gene flow between the species (introgression) may have taken place (Barnes, 1961).

Hybridization and gene flow might be one explanation for a portion of the substantial polymorphism and morphological variation found in *P. grandidentata* and *P. tremuloides.* However, the observed variation might also be due simply to the normal variation among pure individuals of these species. Thus it is important to understand the morphological variation within each species as thoroughly as possible before attributing part of it to hybridization and gene flow. Also, such information is needed in order to distinguish natural F_1 hybrids and first and second generation backcrosses from the parent species. This would be a basic step in determining the amount of gene flow occurring naturally between the species.

Although substantial morphological variation within and among clones of both species has been documented (Barnes, 1961, 1969; Andrejak & Barnes, 1969), the extent of our knowledge of this variation is inadequate, particularly regarding the amount of variation within half- and full-sibling families.

The purpose of this paper is to report the results of a study of morphological variation that was undertaken to assess the nature and extent of variation within and between families of *P. tremuloides.*

In 1968, a series of controlled pollinations was made between aspen species. Care was taken to ensure that the parent clones, located in Washtenaw and Livingston counties in southeastern Lower Michigan were "pure" individuals of the species. Three seed parents (20, 52, 86) were chosen on the basis of bark and foliage; three pollen parents (red, orange, yellow) were chosen on the basis of bark, foliage, and pollen abortion (less than 3%). Seeds from the controlled pollinations and seeds collected from open pollination (OP) were obtained in 1968 and the seedlings outplanted in 1969 in a common garden at the University of Michigan Matthaei Botanical Gardens. The plantation of about two hectares is located on flat to gently sloping terrain characterized by sandy loam and loam soil.

Intact shoots bearing "early" leaves were collected between July and September of 1976 from 148 eight year-old seedlings. Nine families were sampled. Seven of the families (127 seedlings) were the result of controlled pollinations, and two (21 seedlings) were the result of open pollinations in nature. To minimize the effects of within-tree variation, standard shoots were collected using the sampling technique of Barnes (1969). Collections comprised lateral and terminal shoots 25-70 mm long from the inner portions of the middle and lower crown of the tree. A minimum of five shoots with intact leaves was collected from each individual and pressed and dried.

Four shoots and their leaves were then selected from each tree for measurement. Four characters were scored or measured on shoots and their terminal buds:

1. Shoot length (mm)
2. Shoot pubescence (scored 0.0-7.0)
3. Lower terminal bud scale pubescence (scored 0.0-7.0)
4. Upper terminal bud scale pubescence (scored 0.0-7.0)

Pubescence was evaluated because *P. tremuloides* and *P. grandidentata* have distinctly different amounts of terminal bud scale pubescence, and the character previously had been found to be one of the best diagnostic characters for the identification of F_1 hybrid aspens (Barnes, 1961; Andrejak & Barnes, 1969). There was some margin for error in the estimates because the pubescence was partially deciduous and decreased a small amount over the collection period, and shoots and buds in some cases were covered with sooty mold. Shoot length was recorded only to ensure that collections were consistent; it was not considered to be a character differentiating the species.

One standard early leaf (from the middle portion of the shoot) was measured from each of the four shoots from each tree. Seven characters were scored or measured:

1. Maximum blade width (mm)
2. Blade length (mm)
3. Point of maximum width (distance from point of midrib juncture with blade base to point of maximum width) (mm)
4. Petiole length (mm)
5. Number of teeth per leaf side
6. Tooth size (scored 1.0-8.0)
7. Tooth regularity (scored 0-2)

Some of these characters had also been useful in previous studies of aspen foliage (Barnes, 1975). Blade length and the number of teeth along one margin had effectively separated *P. tremuloides* from *P. grandidentata* (Andrejak & Barnes, 1969). Blade length and tooth number had separated hybrids from parental species (Barnes, 1961). Point of maximum width was used as an index to leaf shape, while tooth regularity was a character of the leaf margin as a whole, evaluating the similarity in size of serrations. Margins with teeth that were all approximately of the same size scored as zero; margins with somewhat irregular teeth scored as one; and margins with extremely irregular teeth were given a two. The ratio of blade width to blade length was computed as a twelfth character, for a further index to leaf shape.

The four sets of measurements (one from each shoot) for each tree were then averaged, and the mean values for each individual were used in the statistical runs.

The means, ranges, standard deviations, and coefficients of variation were calculated for each family. A univariate, one-way analysis of variance (ANOVA) and a multicharacter, one-way analysis of variance (MANOVA) were performed on the different families. Twelve characters were used for the ANOVA. Eight characters were used for the MANOVA.[1] A correlation matrix was computed to examine the interrelationships among the characters.

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[1] Shoot length, blade width/blade length, shoot pubescence, and upper bud pubescence were the excluded characters.

Canonical variates analysis was performed using a version of the UCLA Bimed program 7M from the means of the individual trees. Eight characters were again used. Canonical variates are transformations of the input data into independent variables that maximize the differences among groups being compared. The first canonical variate accounts for the greatest variation between group means. The second axis, perpendicular to the first, accounts for the next greatest amount of variation between groups. Dancik & Barnes (1975) found canonical variates analysis to be particularly effective for displaying the differences among individuals and taxa.

A general description of the total population is followed by consideration of the variation among and within families. Results from open-pollinated trees were combined with those from the controlled-pollinated trees because no essential differences were found between them.

General Description

The individuals varied markedly in morphology, as shown by the plot of the first and second canonical variates which combines eight morphological characters (Fig. 1). The individuals were widely distributed along both the horizontal and vertical axes.

Leaves of the 148 individuals typically were broadly ovate. The mean ratio of blade width/blade length was 1.01 (range 0.84-1.29), with mean blade width 51.1 mm (range 40.0-66.8 mm) and mean blade length 51.0 mm (range 36.3-70.0 mm) (Table 1). These figures were consistent with results from

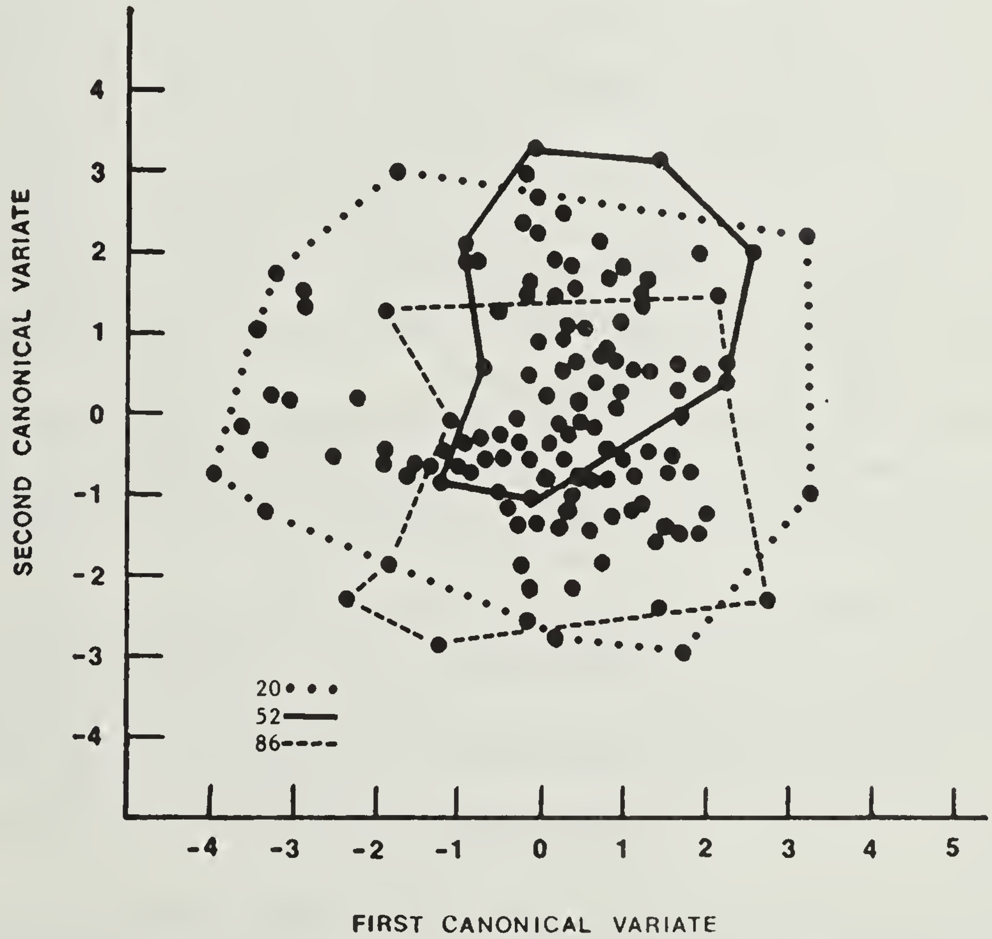


Fig. 1. Plot of first and second canonical variates of members of 9 families of *P. tremuloides* growing in a common garden at the University of Michigan Botanical Gardens, using 8 morphological characters. Lines indicate members of 3 families of the seed parents.

TABLE 1. Means, ranges, standard deviations, and coefficients of variation for 148 individuals of 9 families of *P. tremuloides* growing in a common garden at the University of Michigan Matthaei Botanical Gardens.

Character	Mean	Range	Standard Deviation	Coefficient of Variation (%)
Blade width (mm)	51.1	40.0 -66.8	5.0	9.8
Blade length (mm)	51.0	36.3 -70.0	6.0	11.8
Point of maximum width (mm)	15.8	9.8 -22.0	2.2	14.2
Shoot length (mm)	43.3	25.0 -62.3	8.3	19.2
Tooth number	31.2	23.8 -40.5	3.5	11.1
Tooth size (score)	2.3	1.0 - 4.0	0.7	30.7
Petiole length (mm)	40.5	29.3 -53.8	4.9	12.2
Lower bud pubescence (score)	0.1	0.0 - 1.8	0.2	165.7
Shoot pubescence (score)	0.0	0.0 - 0.0	–	–
Ratio of blade width: length	1.01	0.84- 1.29	8.3	8.3
Upper bud pubescence (score)	0.0	0.0 - 0.0	–	–
Tooth regularity (score)	1.0	0.0 - 2.0	0.5	43.8

earlier studies of 30 clones in northern Lower Michigan (Barnes, 1969) and 14 clones in southeastern Lower Michigan (Andrejak & Barnes, 1969). Although the leaves were smaller in northern Lower Michigan and larger in southeastern Lower Michigan as compared to this study, clones in all three studies had similar ratios of blade width to blade length.

The average number of serrations per leaf side was 31.2 (range 23.8-40.5). Similar findings had been reported in the two previous studies. The mean tooth number in northern Lower Michigan was 30.5 (Barnes, 1967); in southeastern Lower Michigan it was 31.4 (Andrejak & Barnes, 1969). The range in tooth number in northern Lower Michigan (22-39) was also similar to that in this study (24-41). It is interesting that tooth numbers in all three studies were so similar, since the ages of the trees involved were very different: age 8 in the plantation, 26 in the northern Lower Michigan stands, and 13 in the southeastern Michigan stand.

The mean petiole length of 40.5 mm (range 29.3-53.8 mm) (Table 1) was midway between the mean petiole lengths of aspen in the other studies: 35 mm in northern Lower Michigan and 48 mm in southeastern Lower Michigan.

Although identification manuals invariably state that the terminal buds are glabrous, the lower bud scales exhibited very slight pubescence. The mean lower bud pubescence was 0.1 (range 0.0-1.8) (Table 1). Earlier, Barnes (1967) had reported sparse pubescence on basal bud scales of clones in northern Lower Michigan. No pubescence was found on the upper bud scales or the shoots.

Significant ($P < .01$) and moderately strong correlations were found between blade width and blade length ($r = 0.72$) and between blade length and the point of maximum width ($r = 0.66$). Correlations between tooth number and blade width ($r = -0.02$) and between tooth number and blade length ($r = 0.10$) were not significant ($P > .05$).

Variation Among Families

Leaves and the shoots from individuals of the same family tended to have characteristic similarities in appearance. This is apparent in the silhouettes of typical leaves of eight families (Fig. 2). Characteristic family leaf shapes were oval (52 OP), subreniform (86 OP) and orbicular (52 X yellow). Leaf tips were cuspidate (52 OP) or acuminate (52 X red), and leaf margins ranged from finely serrate (52 X yellow) to very strongly serrate (20 X yellow).

The shape of the base of the leaf blade did not seem to be important as a family characteristic. Base shapes varied among families, but no one shape was typical of a family.

Family similarities could also be recognized when leaves of the families were compared with their respective parents (Fig. 3). For example, the leaves of male parent red were markedly different in shape from leaves of seed parents 20 and 86. Red leaves were more elongate (longer than wide) than the more orbicular or subreniform shapes (wider than long) of leaves of 20 and 86. The leaves of families 52 X red, 86 X red, and 20 X red (Fig. 2) tend to show the more elongate influence of the red parent compared to leaves of families 86 OP, 86 X yellow, and 20 X yellow which are orbicular to subreniform.

The different families were so distinct that the trained observer could often identify the family of an individual from just a few leaves. When each family from Figure 1 was plotted separately, individuals clustered by family (Fig. 4). In many cases, family members tended to assort according to family into relatively discrete sections of the plot (Fig. 5).

One-way ANOVA showed that family means were significantly different ($P < .05$) for nine of the 12 characters. The exceptions were pubescence of lower and upper bud scales and shoot pubescence. However, lower bud pubescence was significant at $P < .07$. A multi-character analysis of variance similarly showed that family means were significantly different ($P < .01$). In the canonical variates analysis, families differed most in tooth regularity, lower bud pubescence, and tooth size.

There was some evidence of maternal effects in the canonical variates plot (Figure 1). The families of seed parents 52 (52 X red, 52 X yellow, 52 OP) and 86 (86 X red, 86 X yellow, 86 OP) definitely clustered according to maternal parent. The clustering was along both axes, indicating similarities in tooth regularity, lower bud pubescence, and tooth size. Families of seed parent 20 (20 X orange, 20 X red, 20 X yellow), however, did not group together. Individuals in these families were widely spaced along both axes. No paternal effects were evident in the canonical variates plots.

Variation Within Families

Variation within families, as might be expected, was not as great as variation among families. Nevertheless, considerable variation did exist, and some families showed more than others. The canonical variates plot of all individuals of the family 20 X red (see Fig. 4), for example, showed much

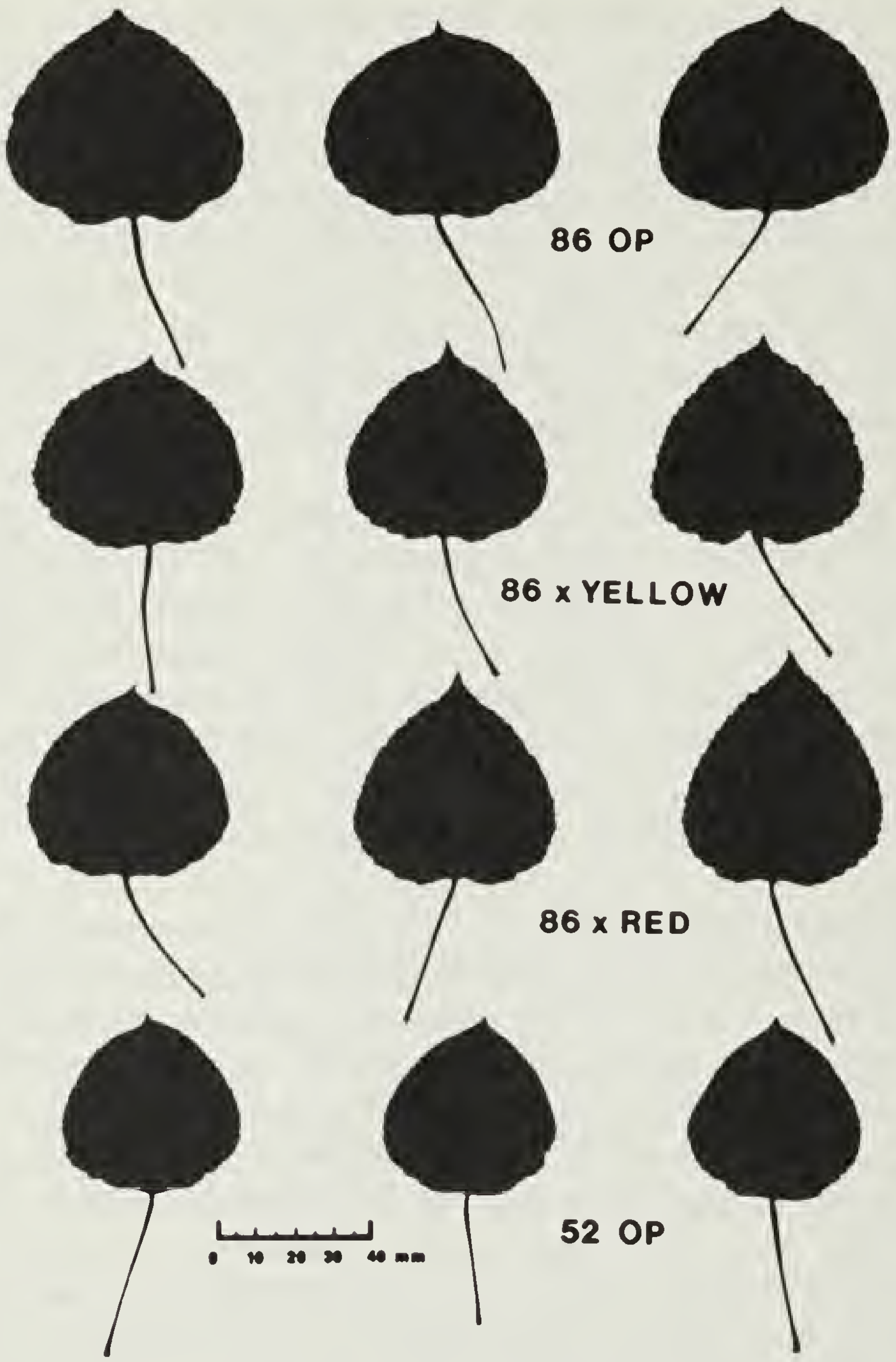
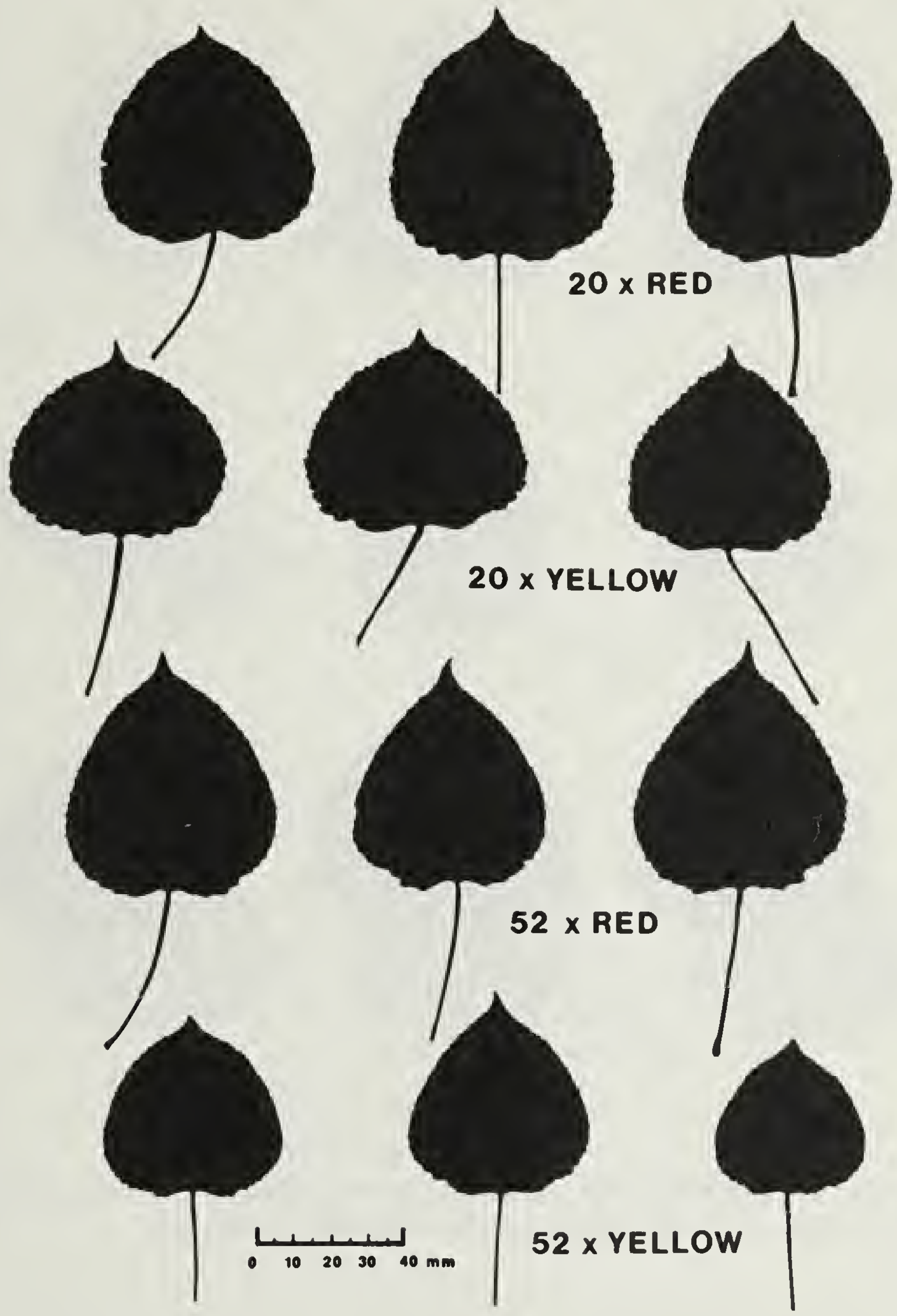


Fig. 2. Silhouettes of early leaves from typical members of 8 families of *P. tremuloides* growing in a common garden at the University of Michigan Botanical Gardens.

separation of the individuals. Standardized leaves from members of this family (Fig. 6) exhibited a variation that was almost as great as the variation among all of the families. Leaf shapes were mostly oval (leaf 8) but could be orbicular (leaf 3) or subreniform (leaf 9). Leaf tips were cuspidate (leaf 3) or acuminate (leaf 2). The bases varied from rounded (leaves 6 and 14) to subcordate (leaves 1 and 7). Margins were crenate-serrate (leaf 2), finely and shallowly serrate (leaf 8), or strongly serrate (leaf 4).

For a given character the coefficient of variation for the families was relatively similar, indicating that each character had about the same degree of variability (Farmer, 1977). However, certain families had a much higher or lower variation than other families in certain characters. For example, 52 X yellow had a much higher variation in tooth number than the other families, 20 X red had a higher variation in tooth size, and 20 X orange had a



much higher variation in lower bud pubescence and tooth regularity than the other families. The family 52 OP had a low variation in tooth size, and 86 OP had a low variation in lower bud pubescence. Open-pollinated clones did not show more variation than controlled crosses, despite the potential of a more heterogeneous male gene pool. However, this may have been due to the small sample sizes for these families, only 11 and 10 trees, or that each seed parent may have been pollinated by a single adjacent male clone in nature.

Discussion

The large variation in morphology within a relatively small gene pool (even within individual full-sibling families) collected from a localized area leads to several considerations. First, the potential for variation of clones

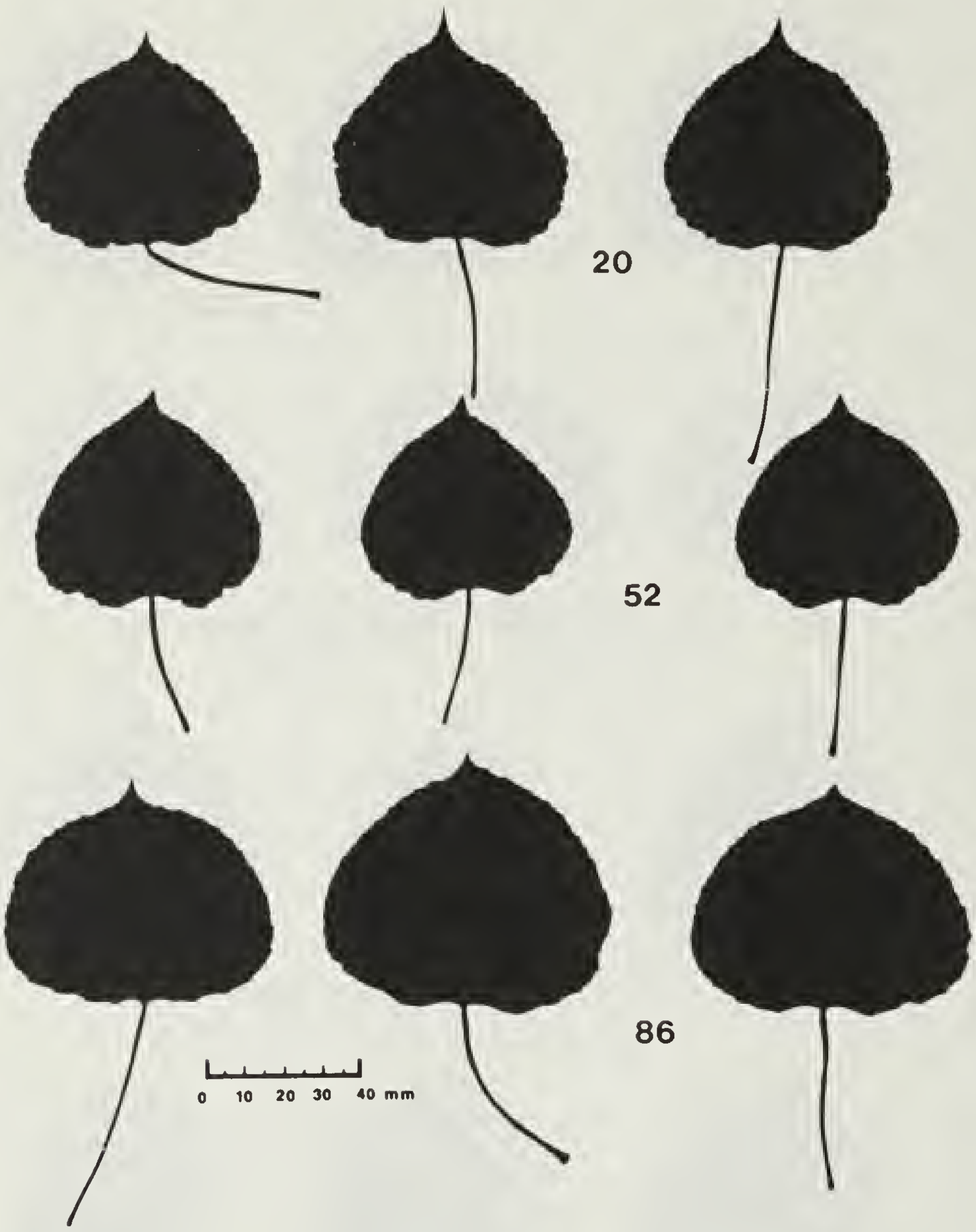


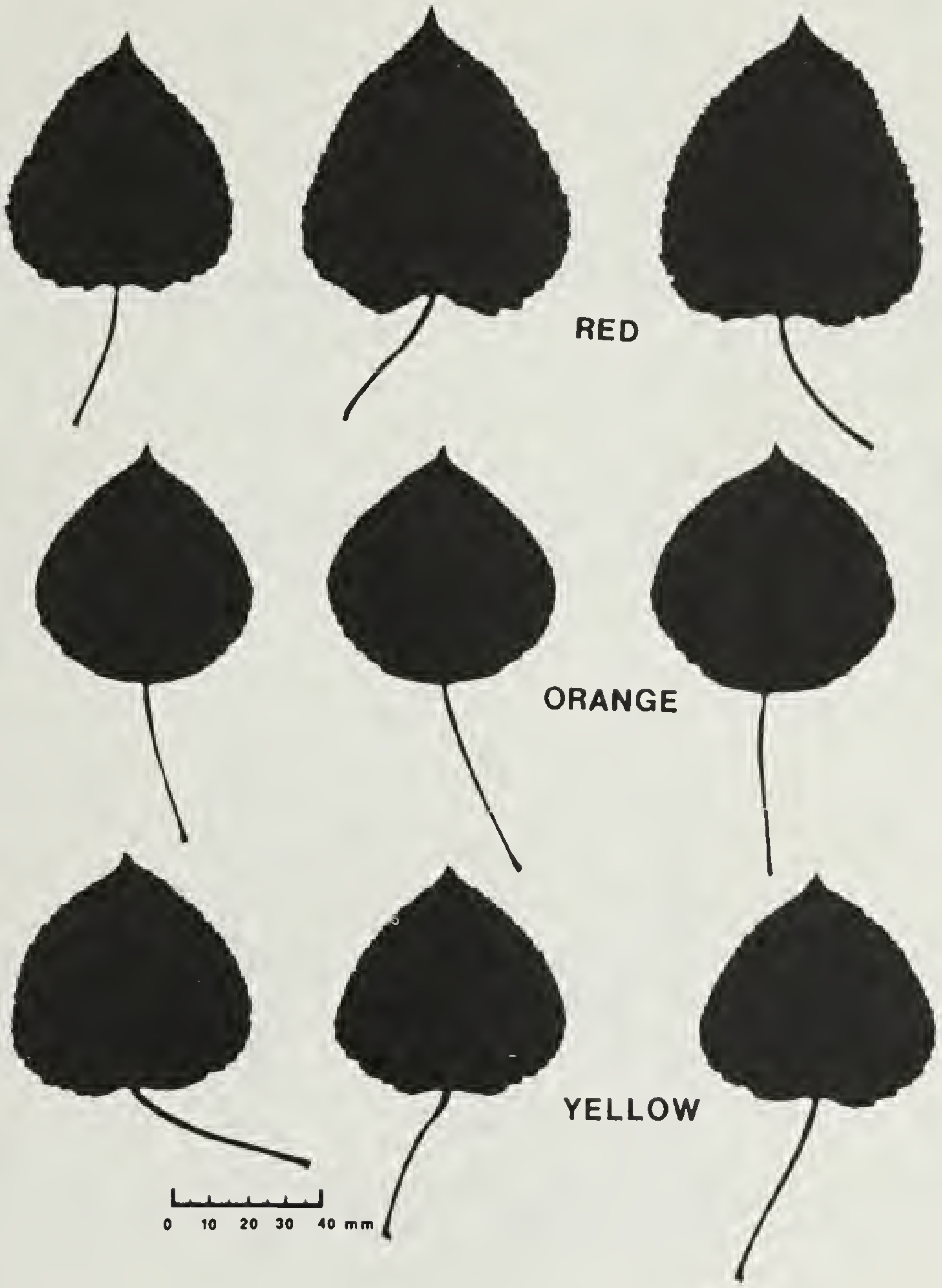
Fig. 3. Silhouettes of early leaves from clones of *P. tremuloides* that were seed parents (left) and pollen parents (right) for individuals of the common garden site.

encountered in the field, where a much larger gene pool is operative, is very large. Thus the marked variation among clones demonstrated by Barnes (1969) in northern Lower Michigan and by Andrejak & Barnes (1969) in southeastern Lower Michigan is not surprising.

Second, such variation increases the difficulty of reliably identifying first and second generation backcrosses to *P. tremuloides* in the field. Morphological characters, particularly those of leaves and shoots, are the features of plants that are most commonly used for species identifications because of their convenience for field use. However, the large variation in aspen morphology may limit reliability of such characters for detecting gene flow. Pollen abortion percentage (Barnes, 1978) or chemical techniques, combined with morphological features, may provide more reliable methods for assessing gene flow.

SUMMARY

Seedling clones of nine full-sibling and half-sibling families of *P. tremuloides* were studied to determine the extent of variation in selected leaf, shoot, and bud characters.

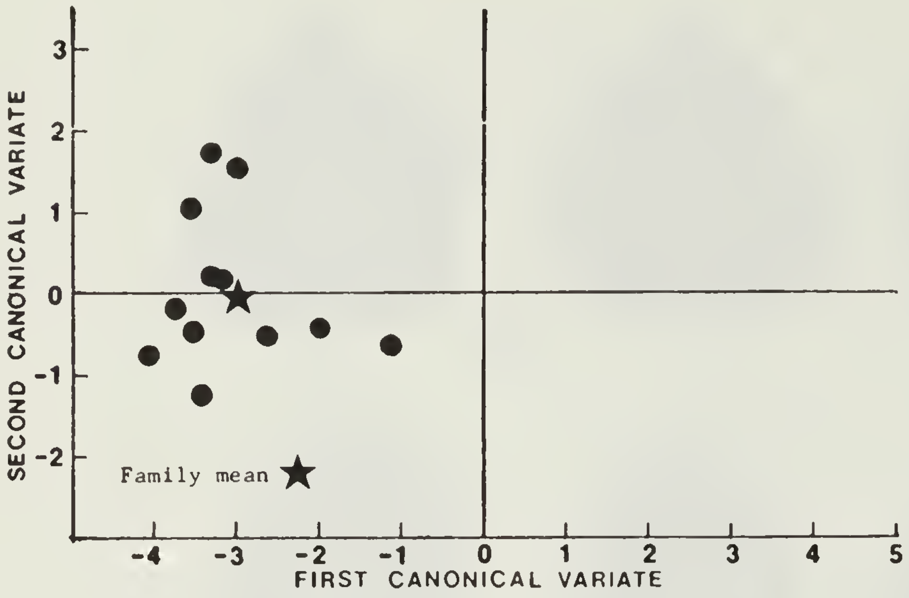


The objectives were to describe the general variation of the population and particularly the variation among and within the families.

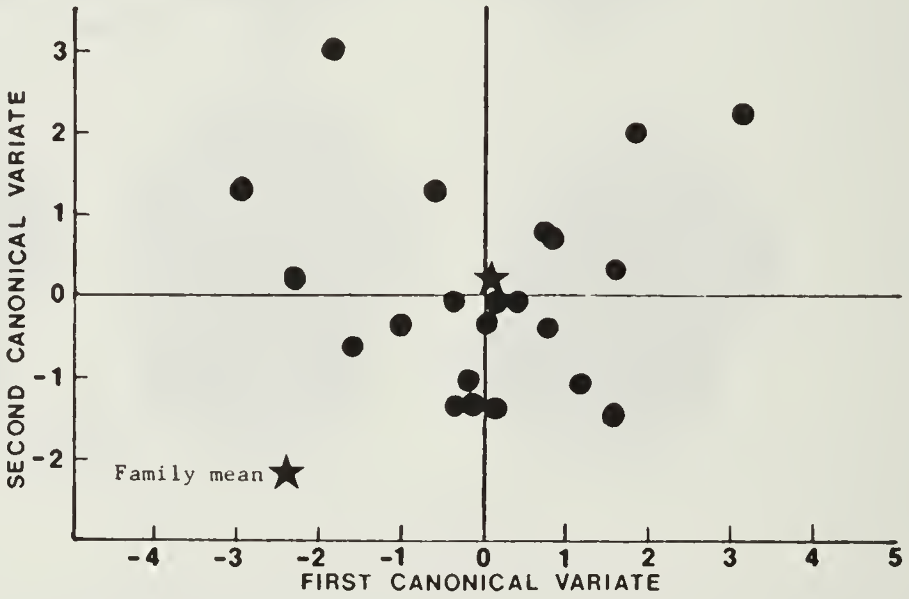
Intact shoots bearing "early" leaves were collected in the summer of 1976 from 148 eight year-old seedlings that had been planted in 1969 in a common garden at the Matthaei Botanical Gardens of the University of Michigan. Seed and pollen parents were located in a small portion of the species' range in southeastern Lower Michigan. Collections were standardized as to the location of shoots within the tree, length of shoots, and position of leaves measured along the shoot.

Large morphological differences were found among families; the variation within families was less, but individuals were not highly uniform. Members of a family typically had a distinct similarity in appearance that distinguished them from members of other families of the study population. The greatest differences among families were in tooth regularity, lower bud pubescence, and tooth size. Evidence of maternal effects was found.

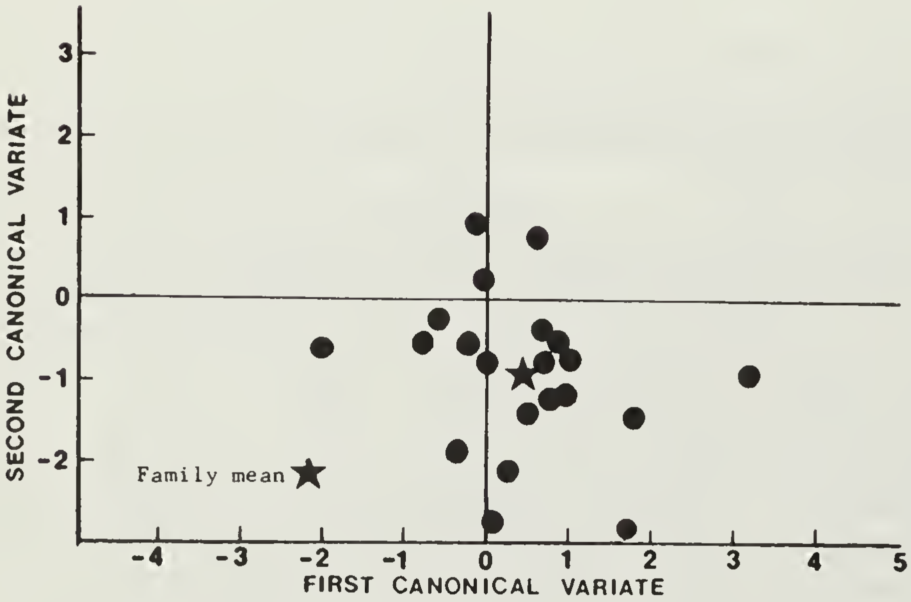
The large variation within a small gene pool reinforces earlier findings of large morphological variation for the species. It may limit the usefulness of morphology for field identification of first and second generation back-crosses to *P. tremuloides* and hence increase the difficulty of establishing the occurrence and extent of gene flow between aspen species. Other characters, such as pollen and chemical traits, should also be employed.



The family 20 x Orange.

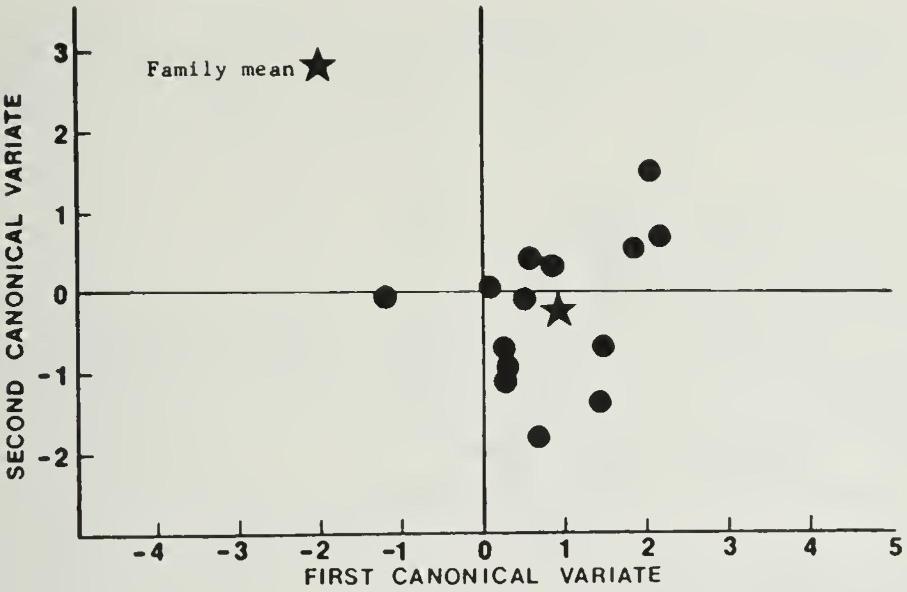


The family 20 x Red.

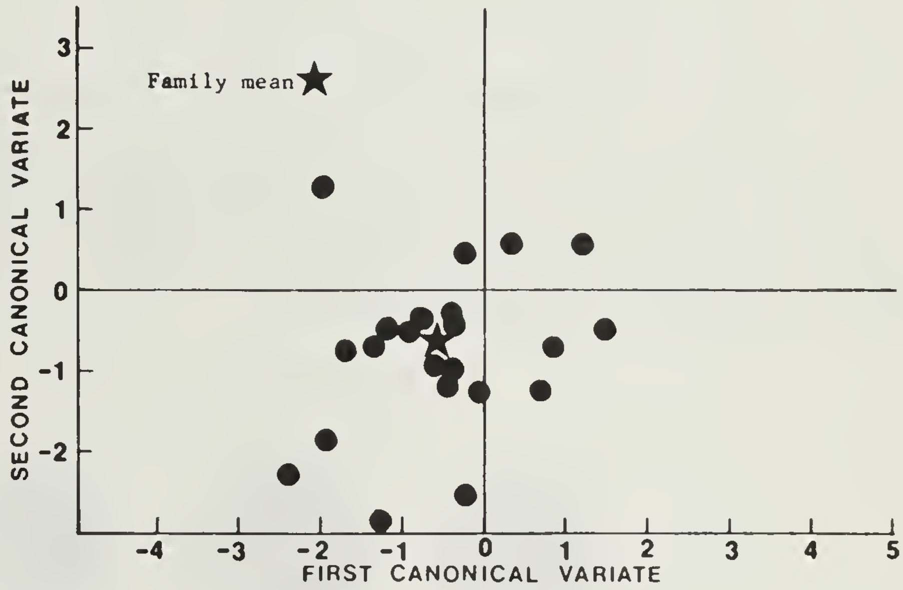


The family 20 x Yellow.

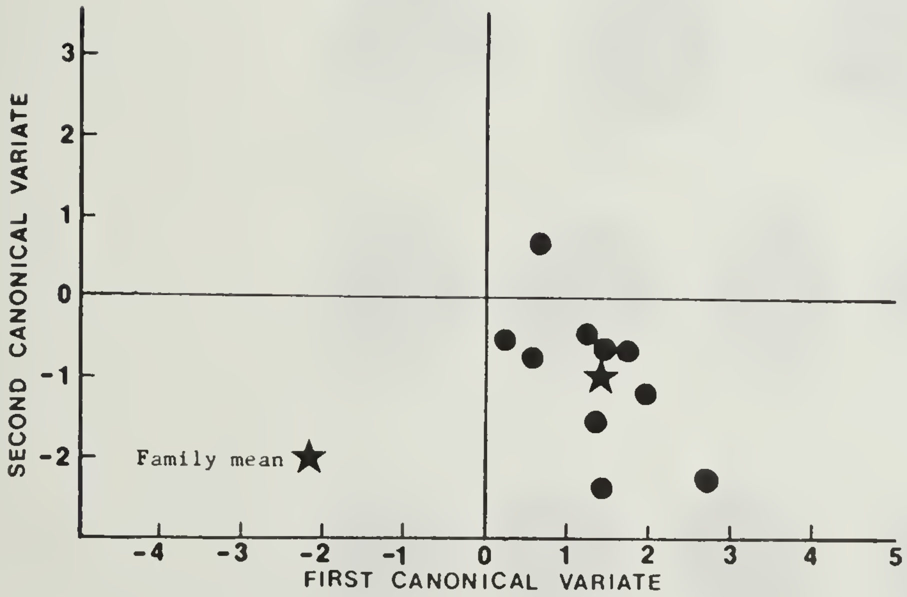
Fig. 4. Family differences in 8 morphological characters illustrated by canonical variates plots. *Left*—3 families of seed parent 20; *right*—3 families of seed parent 86.



The family 86 x Red.



The family 86 x Yellow.



The family 86 OP.

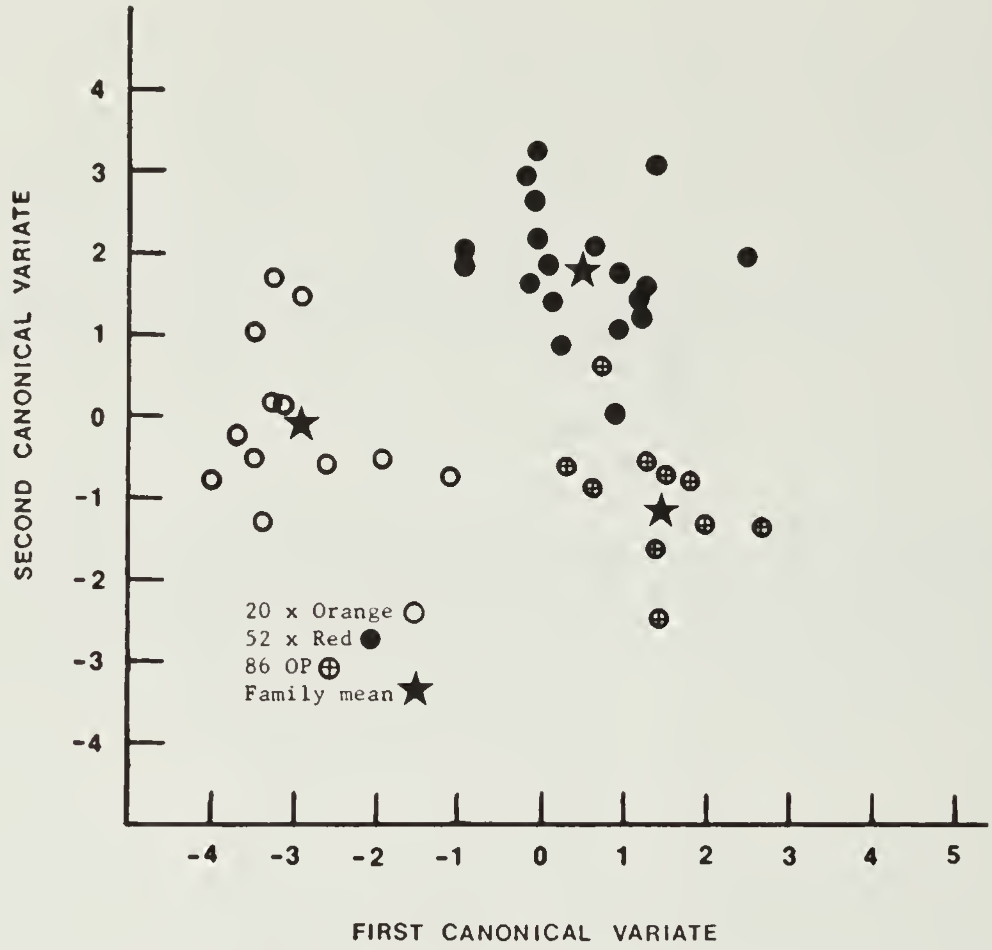


Fig. 5. Plot of first and second canonical variates of members of 3 families of *P. tremuloides*, using 8 morphological characters.

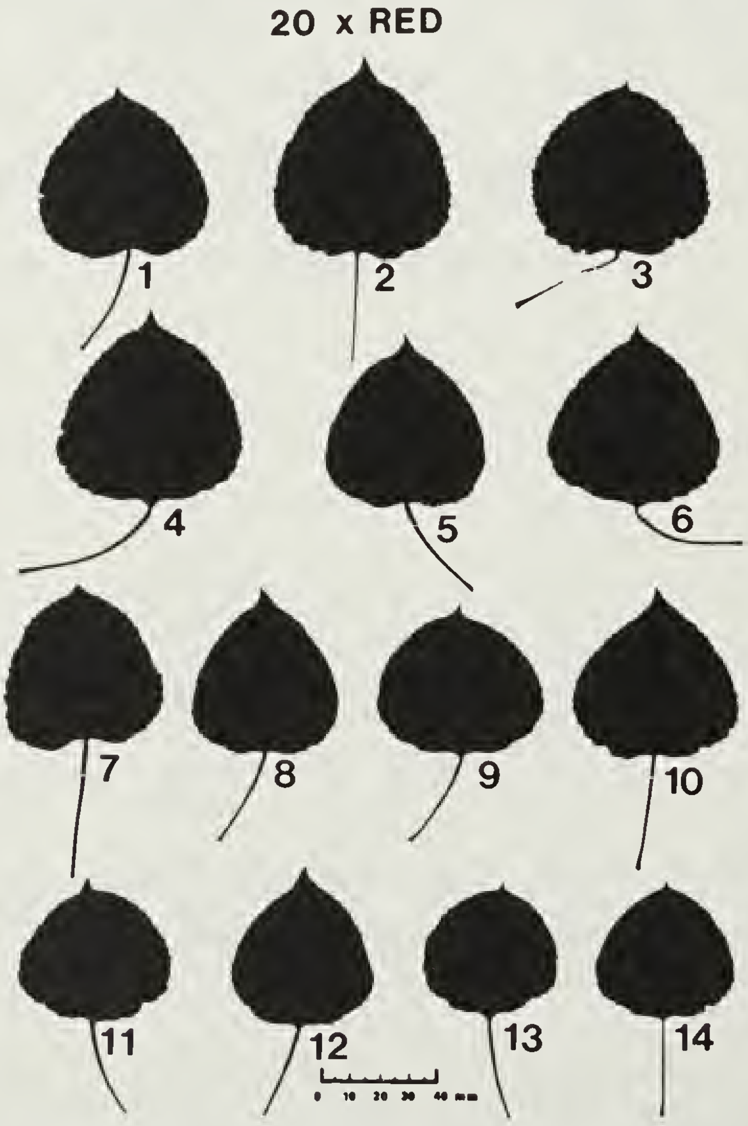

20 x RED
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0 10 20 30 40 mm

Fig. 6. Silhouettes of early leaves from members of the *P. tremuloides* family 20 × Red, illustrating differences in leaf appearance.

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PUBLICATIONS OF INTEREST

A GUIDE TO THE LITERATURE ON THE HERBACEOUS VASCULAR FLORA OF ONTARIO 1977. By James L. Hodgins. 25 pp. $2.00 (from author at 90 Wolfrey Ave., Toronto, Ontario, Canada, M4K 1K8). A Xeroxed document, apparently in preliminary form, which should prove useful as a guide to local lists for various counties, districts, and municipalities in Ontario. There is also a "partial index of monographs relating" to the Ontario flora–with "monograph" meaning almost anything dealing with one or more herbaceous species. Unfortunately, volume numbers are often omitted for journal articles and pagination is never given; titles which are parts of series are usually not identified as such, even though many libraries will catalog them only that way (e.g., Cranbrook Inst. Sci. Bull., Regnum Vegetabile). There is a list of public herbaria in Ontario and a list of sources for maps. The author solicits criticisms, but since one list is labeled "preliminary" and the other "partial," he is protected from accusations of incompleteness or bias toward fairly recent literature. –E. G. Voss

LICHENS OF THE STRAITS COUNTIES, MICHIGAN. By Richard C. Harris. 1977. 150 pp. $10.00 (from author, University of Michigan Herbarium, Ann Arbor, 48109). A limited edition of a preliminary set of keys to over 400 species from Chippewa, Mackinac, Emmet, Cheboygan, and Presque Isle counties, with 168 figures and a checklist of Michigan lichens (ca. 600 spp.) in which the names and authorities have been critically checked as far as possible. –E. G. Voss

WISCONSIN SCIENTIFIC AREAS 1977. Preserving Native Diversity. Wisconsin Department of Natural Resources Tech. Bull. 102. 1977. 52 pp. Although this has the same number of pages as the previous edition (noted in The Michigan Botanist 13:191. 1974), the pages are twice as large. Included are highlights of 1973-1977, during which period 34 new areas were designated as state scientific areas and some 400 investigated. –E. G. Voss

A FIELD GUIDE TO EDIBLE WILD PLANTS OF EASTERN NORTH AMERICA. By Lee Peterson. 1978 (March 17). xiv + 330 pp. Illus. Houghton Mifflin Co., 2 Park St., Boston, 02107. $8.95 (cloth). The easy means of identification and preparation as food are given in attractive form for nearly 400 species. In addition to the taxonomic arrangement of the main portion of the book, detailed treatments of habitat and uses (candy, beverages, jams, etc.) make for an unusually interesting book, beautifully illustrated by photographs in color and excellent line drawings (most of the latter by Roger Tory Peterson, the author's father). –H. Crum

GARDENING IN THE UPPER MIDWEST. By Leon C. Snyder. 1978 (March 24). 292 pp. Illus. University of Minnesota Press. Minneapolis, 55455. $10.00 (cloth). This is a good, straightforward guide to the care of gardens in the harsh climates of Minnesota and adjacent areas. Information is given on such topics as soil treatment, pruning, pest control, landscaping, lawn care, and times of seeding. –H. Crum

THE WOODY PLANTS OF SPHAGNOUS BOGS OF NORTHERN NEW ENGLAND AND ADJACENT CANADA. By Fay Hyland & Barbara Hoisington; illustrated by Laurel Smith. Bull. 744, Life Sciences & Agricultural Experiment Station, University of Maine, Orono. 1977. 110 pp. Many New England bog plants are also in the Great Lakes region, so this illustrated guide may be of local interest. But the drawings often fail to convey the aspect of the plant (e.g. the few fruits of poison sumac on a disembodied erect stalk). The key will be rough for the inexperienced, especially those who do not know the difference between gymnosperms and angiosperms; staminate plants of *Arceuthobium pusillum* must have seeds in an ovary and the leaves deciduous–and in the text one reads erroneously that this species grows in Europe; *Empetrum* has stems "without hairs" but branchlets "pilose"; common blueberries are only 5 cm tall. –E. G. Voss

LICHENS OF THE MACKINAC STRAITS REGION.
II. CANDELARIELLA MÜLL. ARG.

Richard C. Harris and William R. Buck

University Herbarium and Department of Botany
University of Michigan, Ann Arbor 48109

Candelariella is characterized by bright-yellow apothecia and by a bright-yellow crustose or indistinct thallus. The apothecia are lecanorine, and the spores are simple or 2-celled, 8-many/ascus. The primary yellow pigment is calycin which is KOH . (Superficially similar bright-yellow species of *Caloplaca* are KOH+ purple.) *Candelariella* is the largest genus of the Candelariaceae, containing approximately 40 species (Poelt in Hale & Ahmadjian, 1974).

Four species are known to occur in Michigan. In the process of reviewing the genus in the Straits region it became obvious that one of the four had previously been neither distinguished nor described. Most often it has been confused with *C. xanthostigma* (Ach.) Lett.[1] and also with *Candelaria concolor* var. *effusa* (Tuck.) Merr. & Burnh. or, when exceptionally well developed, with *Lepraria candelaris* (L.) Fr. *s. lat.* This new species is characterized by its sorediate thallus and by polysporous asci.

Candelariella efflorescens Harris & Buck sp. nov.–Thallus ad initium constans ex areolae granulosae rotundatae vel irregulariter crenulatae, 90-150 µm diam. Areolae mox in soralios parvos erumpentes. Soredia 20-50 µm diam. Soralia dispersa vel saepe bene evoluta in crustam leprosam confluentes. Apothecia sat rara. Margo apotheciorum interdum sorediosus. Asci et paraphyses ut in *C. vitellina* et *C. xanthostigma.* Sporae ad 32 in asco simplices vel interdum biloculares, 12-15(19) X 4-5(6) µm.

Thallus initially consisting of granulose areoles which are rounded or occasionally irregularly crenulate, 90-150 µm in diameter. These primary areoles soon break down into small soralia consisting of soredia 20-50 µm in diameter. Soralia scattered or crowded and the soredia proliferating to form a more or less continuous leprose crust. Apothecia uncommon. Apothecial margin occasionally sorediose. Asci and paraphyses as in *C. vitellina* and *C. xanthostigma.* Spores up to 32/ascus, simple or sometimes 2-celled, 12-15(19) X 4-5(6) µm.

Holotype: Michigan, Mackinac County: Edge of swamp across highway from Island Point State Forest Campground (Hog Island State Forest Campground), on trunk of *Populus balsamifera, W. R. Buck,* 5.X.1974 (MICH). Isotypes in H and US.

Figures 1, 3, 5, 6 and 10.

In Michigan *C. efflorescens* occurs in a wide variety of habitats including exposed, isolated trees in old fields, oak-hickory woods, coniferous woods, and *Thuja* swamps. Where their ranges overlap *C. efflorescens* and *C.*

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[1] This name is maintained provisionally. See Laundon (1963) for nomenclatural discussion.

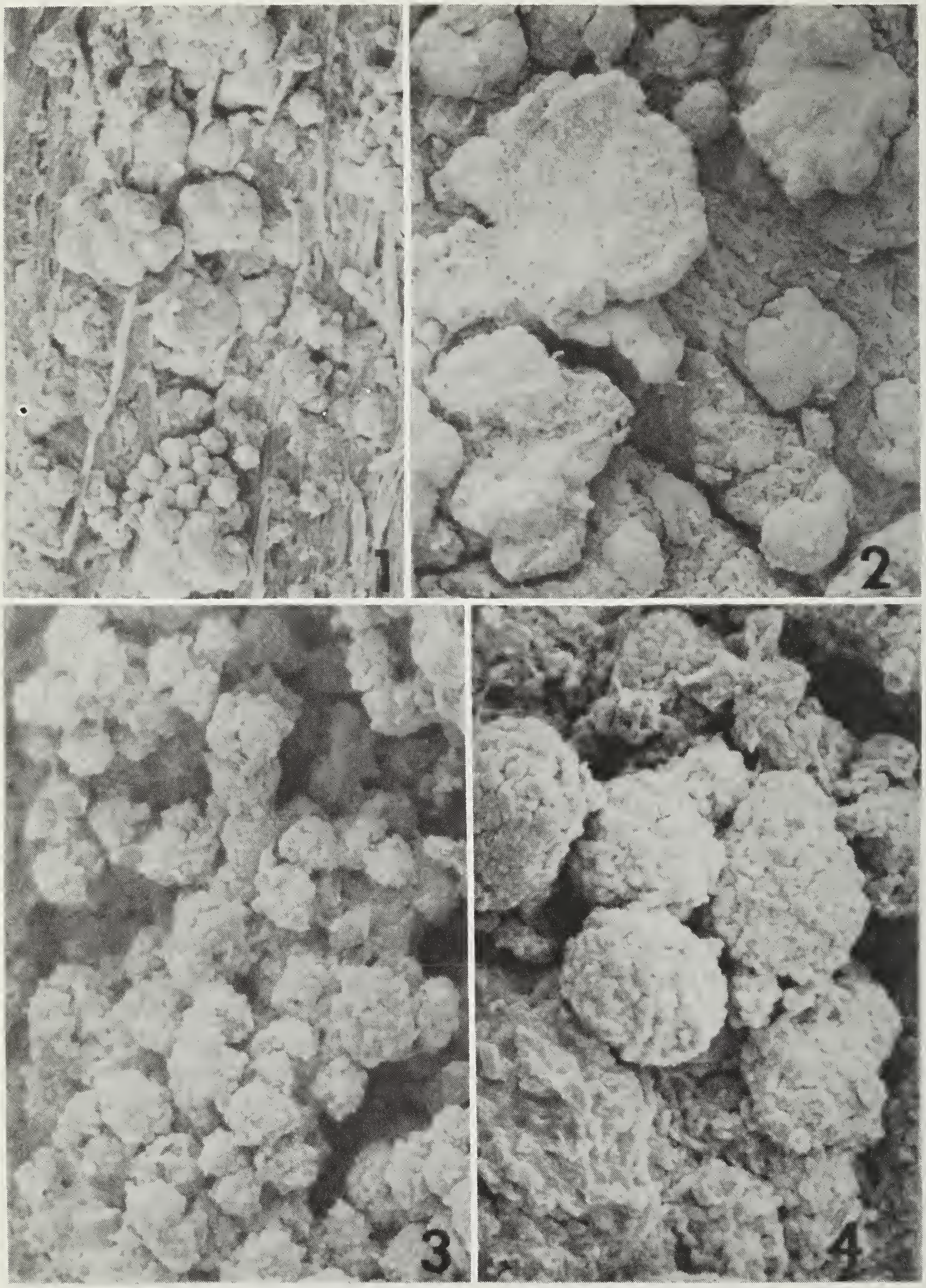

Fig. 1. *Candelariella efflorescens,* × 100, primary areoles in center, developing soralia at top and bottom edges of picture (Harris 9257, Cheboygan Co.). Fig. 2. *C. vitellina,* × 100, apothecium at center left (Lowe 619b, Isle Royale). Fig. 3. *C. efflorescens,* soredia × 300 (Harris 9768, Jackson Co.). Fig. 4. *C. xanthostigma,* areoles, × 300 (Harris 9808, Washtenaw Co.).—All specimens rinsed with acetone to remove calycin crystals before SEM. All photos by W. R. Buck.

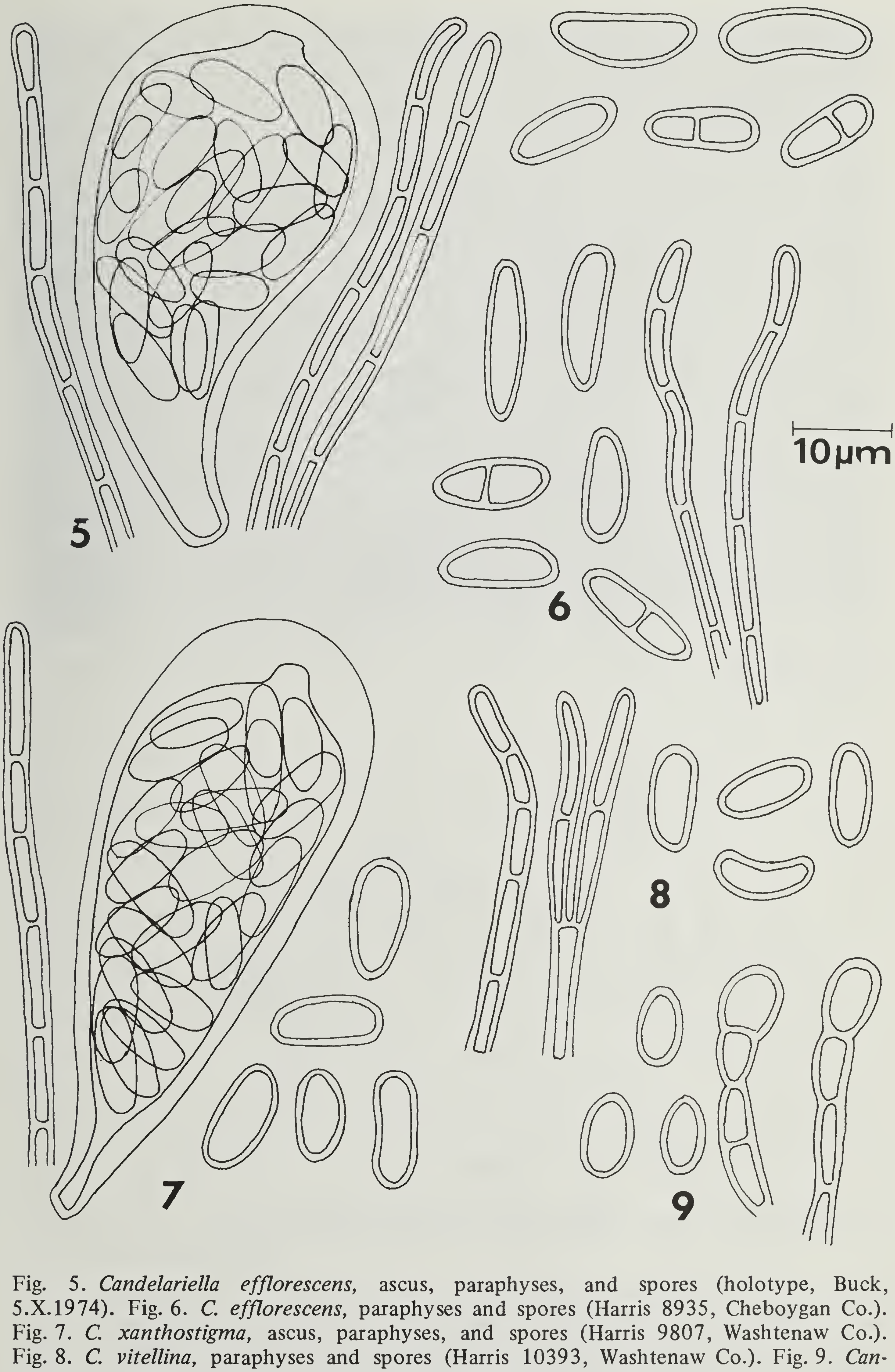

Fig. 5. *Candelariella efflorescens,* ascus, paraphyses, and spores (holotype, Buck, 5.X.1974). Fig. 6. *C. efflorescens,* paraphyses and spores (Harris 8935, Cheboygan Co.). Fig. 7. *C. xanthostigma,* ascus, paraphyses, and spores (Harris 9807, Washtenaw Co.). Fig. 8. *C. vitellina,* paraphyses and spores (Harris 10393, Washtenaw Co.). Fig. 9. *Candelaria concolor,* paraphyses and spores (Harris 9878, Antrim Co.).

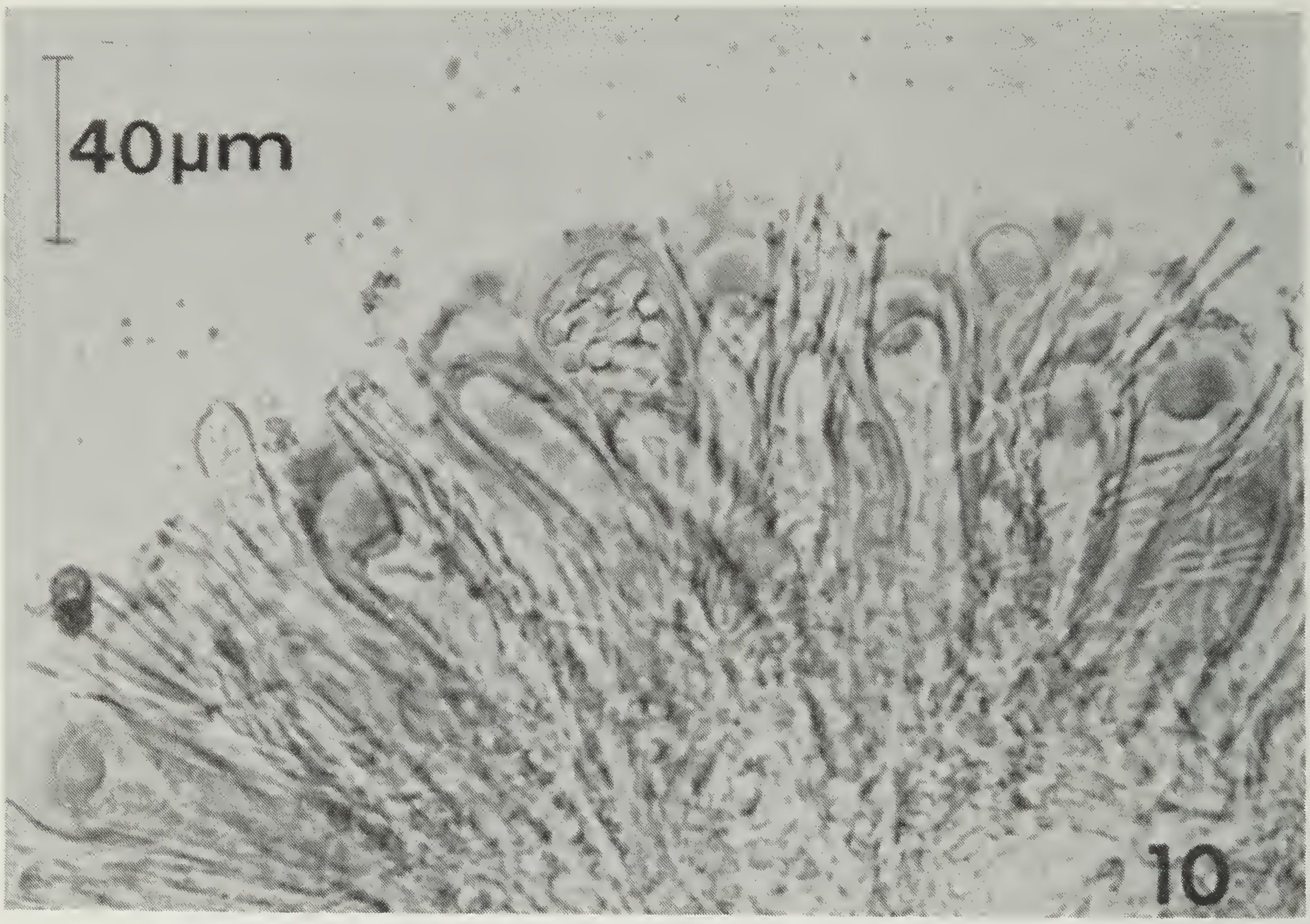

Fig. 10. *Candelariella efflorescens,* hymenium (Brodo 20573, Quebec, Gatineau Co., photo by I. M. Brodo).

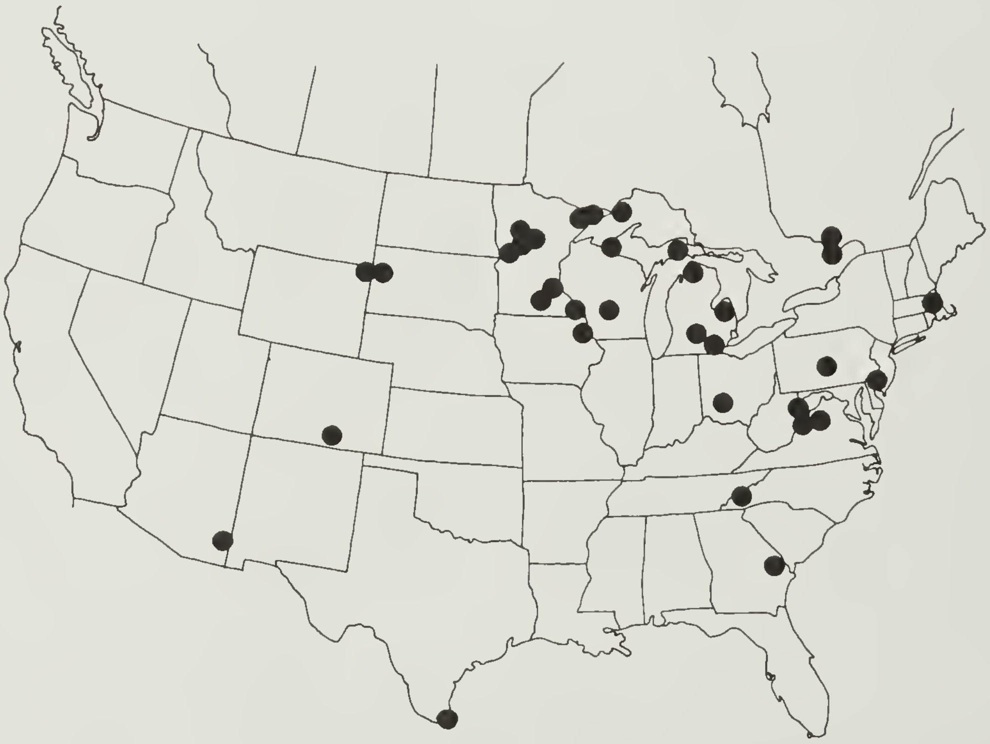

Fig. 11. Distribution of *Candelariella efflorescens.*

xanthostigma often occur in the same habitats. In southern Michigan one can usually find both in any given oak-hickory woods. Of 62 specimens of *C. efflorescens* where the substrate was recorded, 60 percent were on bark of deciduous trees, 30 percent on bark of coniferous trees and 10 percent on decorticated wood. The geographical distribution of *C. efflorescens* (fig. 11) is still poorly known, since, like many usually sterile lichens, it has been rarely collected. In general *C. efflorescens* seems to have a temperate eastern North American distribution, re-occurring in the Rocky Mountains but not penetrating to the Pacific Coast.

The only other species in which the primary granules are reported to break down forming soralia is *C. reflexa* (Nyl.) Lett., illustrated by James [1971, p. 129, f. 4(A)]. However, the asci of *C. reflexa* contain only eight spores and *C. efflorescens* may be considered as the North American vicariad of *C. reflexa* differing by its polysporous asci. Although we have not been able to refer any North American specimens definitely to *C. reflexa,* some western collections might possibly be this or an undescribed species with 8-spored asci. Therefore it is possible that sterile specimens of *C. efflorescens* from the Southwest are incorrectly determined.

Candelariella efflorescens is closely allied to *C. vitellina* and to *C. xanthostigma* in the characters of the apothecia. Given an isolated apothecium we would not be able to distinguish which of the three species it came from. The asci are basically 32-spored (fewer-spored due to abortion); the paraphyses are uniformly slender and the spores essentially the same size (cf. figs. 5-8). The species are readily distinguishable only by their thallus characters. *Candelariella vitellina* is almost always fertile. The thallus consists of mostly flattened areoles with distinctly, but irregularly, crenate outlines (fig. 2). The areoles are usually dispersed but very well-developed specimens may form a continuous crust of overlapping areoles. Occasionally the thallus is almost entirely lacking. *Candelariella xanthostigma* and *C. efflorescens* are only occasionally fertile, and the thallus is always present. The thallus of *C. xanthostigma* consists of rounded, occasionally slightly crenulate granules which are smaller than in *C. vitellina* (fig. 4). The granules are often dispersed but may become crowded in well-developed specimens. The thallus of *C. efflorescens* begins as granules roughly the same size as those of *C. xanthostigma,* but these soon disintegrate to form soralia. The center of the thallus usually consists entirely of soralia or in well-developed material, a continuous leprose crust may be formed, rather similar to that of *Lepraria candelaris.* However, if the margins of the thallus are examined, granules of two different sizes can be found. (The soredia are 1/4 to 1/3 the size of the primary granular areoles.) *Lepraria candelaris* may be separated from well-developed specimens of *C. efflorescens* by its uniformly small soredia. In Michigan *L. candelaris* is also chemically distinct, containing either pinastric acid or calycin and an unknown pulvinic acid derivative, while the *Candelariellae* contain calycin. On the east coast of North America *L. candelaris* may contain calycin only and would have to be distinguished on the basis of morphology.

Specimens of *C. efflorescens* with scattered soralia have been called *Candelaria concolor* var. *effusa,* but in this latter taxon there is always some trace of foliose lobes with soralia at the tips. (In fact Tuckerman's original *Teloschistes concolor* b. *effusa,* judging from his synonymy, seems to have been intended for *Candelaria concolor s. str.*, as opposed to *C. fibrosa* which he also included in his concept of *Teloschistes concolor.*) Also the paraphyses and spores are quite distinct (fig. 9), indicating that *C. efflorescens* is correctly placed in *Candelariella* and is not a very reduced form of *Candelaria concolor.*

The fourth species of *Candelariella* in the Straits region, *C. aurella* (Hoffm.) Zahlbr., differs from the other three in having 8-spored asci. *Candelariella aurella* has been found only on rock (usually calcareous) in our area. *Candelariella efflorescens* and *C. xanthostigma* occur only on bark or rarely decorticated wood while *C. vitellina* occurs on bark, wood and non-calcareous rock.

The Michigan distributions of *C. efflorescens* and *C. xanthostigma* are shown in Fig. 12. *Candelariella efflorescens* is distributed throughout the state while *C. xanthostigma* has a more southern distribution. In general *C. xanthostigma* has a more restricted distribution: Iowa and Wisconsin through the Lower Peninsula of Michigan, southern Ontario to Connecticut, south to Kentucky (but apparently not in the mountains). *Candelariella vitellina* is distributed throughout Michigan, but *C. aurella* is known to us only from the limestone areas in Delta County and the Straits region. Otherwise, both are widely distributed in North America.

The following key is provided to summarize the distinguishing characters of the Michigan species of *Candelariella*:

1. Thallus consisting of more or less dispersed spherical granules or of soredia; apothecia usually lacking 2

1. Thallus of small flattened, usually crenulate areoles or thallus not evident; apothecia usually present 3

  2. Thallus consisting of more or less rounded areoles (not sorediose) 0.05-0.15 mm across, often dispersed but in well-developed specimens becoming crowded and more irregular in form in the center of the thallus;

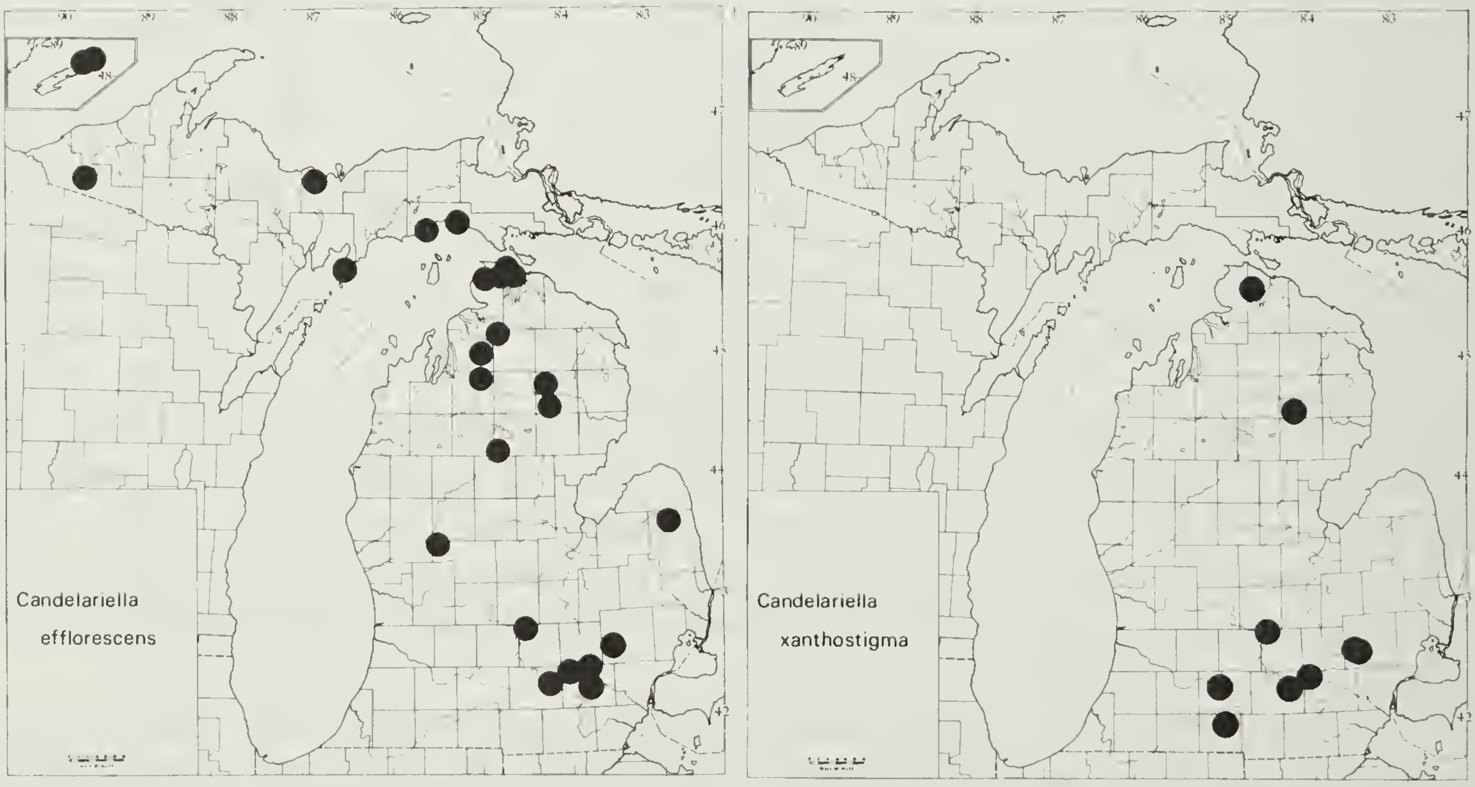

Fig. 12. Michigan distribution of *Candelariella efflorescens* (at left), *C. xanthostigma* (at right).

spores 32/ascus, occasionally 2-celled, 10-15 × 4-6 µm; on deciduous trees and *Thuja;* Lower Peninsula, common southward, rarer northward *C. xanthostigma*

2. Thallus sorediate, beginning as small, rounded or slightly crenulate areoles, 0.09-0.15 mm across, breaking down to form small soralia; soralia often dispersed but in some specimens confluent to form a continuous leprose thallus; soredia 0.02-0.05 mm across; spores 32/ascus, occasionally 2-celled, 12-15(19) × 4-5(6) µm; on deciduous trees and conifers, especially *Thuja;* rather common throughout Michigan *C. efflorescens*

3. Spores 16-32/ascus, rarely 2-celled, 10-18 × 4-5 µm; thallus of small flattened, round or crenate areoles which in some specimens are confluent to form larger cushions, or thallus rarely not evident; growing on bark, old wood and rocks; not uncommon; throughout Michigan *C. vitellina*

3. Spores 8/ascus, simple, 9-12 × 4-5 µm [9-15 × 4.5-6.5 µm (Hakulinen, 1954)]; thallus not evident; growing on rock; rare; Straits region *C. aurella*

We would like to thank I. M. Brodo, M. E. Hale, H. A. Imshaug, and C. M. Wetmore for the loan of specimens and I. M. Brodo for the photograph of the hymenium of *C. efflorescens.*

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Hakulinen, R. 1954. Die Flechtengattung Candelariella Müller Argovensis. Ann. Bot. Soc. Zool.-Bot. "Vanamo" 27(3):1-127.

James, P. W. 1971. New or interesting British lichens: 1. Lichenologist 5:114-148.

Laundon, J. R. 1963. The taxonomy of sterile crustaceous lichens in the British Isles. 2. Corticolous and lignicolous species. Lichenologist 2:101-151.

Poelt, J. 1974. Appendix A, Classification. In Hale, M. E. & V. Ahmadjian. The Lichens. Academic Press, New York.

PTYCHOMITRIUM, A MOSS GENUS NEW TO MICHIGAN

William R. Buck

University Herbarium, University of Michigan
Ann Arbor, 48109

Ptychomitrium is a saxicolous moss genus of predominantly temperate latitudes of both the Northern and Southern Hemispheres. The acrocarpous plants are characterized by leaves with a single costa and short cells, commonly bistratose above, and by capsules erect, exserted, with a single peristome. The calyptra is mitrate and plicate rather than smooth as in *Campylostelium,* the only other genus in the family in North America.

In the United States are five species of *Ptychomitrium,* separated on differences of their leaves and peristomes. Most of the species are confined to the southern and western states but one species, *P. incurvum* (Schwaegr.) Spruce, is known to extend farther north than the others. It is reported from central Indiana (Welch, 1957), southern Ohio (Lesquereux & James, 1884), and southern Ontario at Niagara Falls (Ireland & Cain, 1975). Therefore, it is not totally unexpected that *P. incurvum* would occur in Michigan. However, my recent collection, in southeastern Michigan, is more than 200 miles from other known localities.

The collection was made just outside the southwest city limits of Ann Arbor on the edge of a large pasture and near a small, willow-lined stream. The plants were growing on one of the few rocks in the area (presumably a glacial erratic) along with the other mosses *Entodon seductrix* and *Callicladium haldanianum.* The *Ptychomitrium* had almost mature sporophytes, with the calyptrae still covering the capsules. The collection data are: Washtenaw County, Pittsfield Township, SW of Ann Arbor, in an old field on dry, exposed conglomerate rock, William R. Buck, 27 April 1978. The specimen is deposited in the University of Michigan Herbarium.

LITERATURE CITED

Ireland, R. R. & R. F. Cain. 1975. Checklist of the mosses of Ontario. Publ. Bot. Nat. Mus. Canada, No. 5, 67 pp.

Lesquereux, L. & T. P. James. 1884. Manual of the Mosses of North America. Boston. 447 pp.

Welch, W. H. 1957. Mosses of Indiana. Indianapolis. 478 pp.

MIGHIGAN PLANTS IN PRINT

New Literature Relating to Michigan Botany

A. MAPS, SOILS, GEOLOGY, CLIMATE, GENERAL

Berndt, Loren W. 1977. Soil Survey of Delta County and Hiawatha National Forest of Alger and Schoolcraft Counties, Michigan. U.S. Dep. Agr. iii + 139 + [4] pp. + 112 once-folded map sheets + [6] twice-folded sheets. [Covers all of Delta County plus those portions of Alger and Schoolcraft counties in the project boundaries of Hiawatha National Forest–a total of 1768 square miles. As with other recent surveys, includes full aerial photographic coverage, on a scale of nearly 3″ to a mile, with borders of soil types superimposed. All Michigan soil surveys are available from Soil Conservation Service, 1405 S. Harrison Rd., East Lansing, Michigan 48823.]

Cambray, F. W., John H. Beaman, & M. Hensley. 1977. Geology, vegetation, and vertebrate fauna of Michigan. BioScience 27:349-353. [A brief summary, in preparation for the AIBS meetings at East Lansing, August 1977.]

Dietrich, R. V. 1978. Post-Valders geological history of Beaver Island, Michigan. Mich. Academ. 10:283-297. [Stresses status of the island during Algonquin and Nipissing lake stages, with different conclusions from those of Kapp et al.]

Dohrenwend, R. E. 1978. A Water Balance Approach to Moisture Storage Estimation in Forest Soils. Mich. Tech. Univ. Ford For. Center Res. Note 25. 9 pp. [Data on the average monthly behavior of soil moisture storage in the forested area at Alberta, Baraga Co.]

Drexler, Christopher. 1977. Outlet channels in the Upper Peninsula of Michigan for the post-Duluth lake stages. Mich. Academ. 10:101-113. [Evidence from Baraga and northwestern Marquette counties for the outlets from the western Lake Superior basin as glacial ice retreated.]

Engel, Robert J. 1977. Soil Survey of Washtenaw County, Michigan. U.S. Dep. Agr. iii + 108 + [3] pp. + 56 once-folded map sheets + [6] other folded sheets. [As with other recent surveys, includes general and detailed information on soils and full aerial photographic coverage for the county, thus showing patterns of vegetation as well. A long-awaited replacement for the old survey of this county, in the 1930 series!]

Goldman, A. Lawrence, Jr. 1976. A Field Guide and Sourcebook to Geology of the Eastern Upper Peninsula of Michigan Intended Primarily for Secondary Earth Science Teachers. Dep. Geol. West. Mich. Univ. Publ. ES-3. 88 pp. $4.00. [Deals with Mackinac, Chippewa, Luce, and Schoolcraft counties, including numerous maps of surface geology and drainage, as well as stratigraphic data. Directions are given for 42 specific sites, including municipal sewage and water treatment facilities.]

Larson, Jerry D. 1977. Soil Survey of Wayne County Area, Michigan. U.S. Dep. Agr. iii + 83 + [1] pp. + 53 twice-folded map sheets + [5] twice-folded sheets. [Covers a little more than half of the county, omitting the area in and around Detroit which "is so developed in housing and industry that making a detailed soil survey was not practical."]

Lewis, Jerry D. 1975. Michigan's Industrial Sand Resources. Mich. Geol. Surv. Circ. 11. 33 pp. [Includes general information on character and location of Michigan sands.]

Pregitzer, Karl E. 1978. Soil Survey of Clinton County, Michigan. U.S. Dep. Agr. iv + 89 pp. + 72 twice-folded map sheets + [5] twice-folded sheets. [Supersedes the survey of the 1936 series, published in 1942, with a modern one including full aerial photographic coverage of the county.]

Urie, Dean H. 1978["1977"]. Ground Water Differences on Pine and Hardwood Forests of the Udell Experimental Forest in Michigan. U.S. Dep. Agr. North Central For. Exp. Sta. Res. Pap. NC-145. 12 pp. [Data on geology and soils from Manistee Co.]

(U.S. Geological Survey). The following new topographic maps for Michigan have been published since the previous listing in our May 1977 issue and are available at $1.25

each from Branch of Distribution, U.S. Geological Survey, 1200 South Eads St., Arlington, Virginia 22202. All maps listed here are 7½-minute quadrangles (scale of 1:24,000 or about 2½ inches to a mile) and are new or resurveyed, the former now completing coverage of the state. In addition, photorevisions have been published for another 50 quadrangles, not listed here. Following the name of the quadrangle, the county or counties in which it primarily lies are added.

Alamando [Midland]
Auger Lake [Luce]
Averill [Midland]
Breckenridge [Gratiot]
Buckeye Lake [Luce]
Chelsea [Washtenaw]
Curtis East [Mackinac]
Engadine [Mackinac]
Floyd [Midland]
Fowlerville [Livingston]
Garnet [Mackinac]
Gilchrist [Mackinac]
Gimlet Creek [Luce]
Gordonville [Midland]
Gould City [Mackinac]
Grass Lake [Jackson]
Gregory [Livingston, Washtenaw]
Hog Island Point [Mackinac]
Lakefield [Saginaw]
Leaton [Isabella]
McMillan [Luce]
Merrill [Saginaw]
Millecoquin [Mackinac]
Millville [Ingham]
Mount Pleasant [Isabella]
Naubinway [Mackinac]
Newberry [Luce]
Parkers Corners [Livingston]
Pleasant Valley [Midland]
Point Patterson [Mackinac]
Rathbone [Gratiot]
Roberts Corner [Luce]
Rosebush [Isabella]
Roy Lake [Luce]
Sanford [Midland]
St. Louis [Gratiot]
Soo Junction [Luce]
Stockbridge [Ingham, Jackson]
Webberville [Ingham]
Weidman [Isabella]
Winn [Isabella]

B. BOOKS, BULLETINS, SEPARATE PUBLICATIONS

Hohn, Matthew H. 1977. Guide to the Flora of Beaver Island, Michigan Part I—The Bogs. Central Mich. Univ. Biol. Sta., Beaver Island. 69 pp. $4.25 + $.50 postage. [A guide to almost 150 species, very attractively illustrated with line drawings facing relevant text pages—but only 5 of the latter are free of typographical and other errors (sometimes as many as 6 or 8 per page). Helpful aids include a map of Beaver Island and a non-dichotomous "Guide to the Groups of Plants."]

Thompson, Paul W. 1977. Champion Trees in Michigan—The Big Tree State. Mich. Bot. Club. [7] pp.

Tubbs, Carl H. 1978["1977"]. Natural Regeneration of Northern Hardwoods in the Northern Great Lakes Region. U.S. Dep. Agr. North Central For. Exp. Sta. Res. Pap. NC-150. 20 pp. [Based on studies done in Upper Peninsula and in Wisconsin, including role of sprouts and seedlings; map shows concentrations of northern hardwoods in Minnesota, Wisconsin, and Michigan.]

C. JOURNAL ARTICLES

Ackerman, J. D. 1977. Biosystematics of the genus Piperia Rydb. (Orchidaceae). Bot. Jour. Linn. Soc. 75:245-270. [Distribution map for P. unalascensis shows it in the eastern Upper Peninsula, but no specimens from the Great Lakes region are cited nor used in chromatographic or cytological studies.]

Bezerra, J. L., & J. W. Kimbrough. 1975. The genus Lasiobolus (Pezizales, Ascomycetes). Canad. Jour. Bot. 53:1206-1229. [L. macrotrichus cited from Lower Falls, Tahquamenon River, Luce Co. (undoubtedly from Michigan, though attributed to New York—and the Lower Falls are in Chippewa Co.), and from sites in Cheboygan and Alger cos.; L. monascus cited from Cheboygan Co.]

Buck, William R. 1977. A new species of Selaginella in the S. apoda complex. Canad. Jour. Bot. 55:366-371. [S. eclipes is the species in the western Great Lakes region; drawings in part based on material from Menominee Co., Mich.]

Crow, Garrett E. 1978. A taxonomic revision of Sagina (Caryophyllaceae) in North America. Rhodora 80:1-91. [Distribution maps and citation of representative specimens include Michigan localities for S. nodosa ssp. borealis and S. procumbens. Undocumented is a statement that the latter introduced species had appeared in the iron mining region of Lake Superior several years before iron was even discovered there.]

Frederick, Douglas J., Lawrence Rakestraw, Christopher Eder, & Robert A. Van Dyke. 1977. Original forest vegetation of the Pictured Rocks National Lakeshore and a comparison with present conditions. Mich. Academ. 9:433-443.

Jensen, Richard J. 1977. Numerical analysis of the scarlet oak complex (Quercus subgen. Erythrobalanus) in the eastern United States: Relationships above the species level. Syst. Bot. 1:122-133. [Collections used included one of Q. palustris from Bay City State Park and one of Q. rubra from Tawas Point State Park.]

Kallunki, Jacquelyn A. 1976. Population studies in Goodyera (Orchidaceae) with emphasis on the hybrid origin of G. tesselata. Brittonia 28:53-75. [Based on morphological, cytological, and paper chromatographic studies of populations in northern Michigan together with examination of herbarium specimens from throughout North America; distribution maps for G. oblongifolia, G. repens, and G. tesselata.]

Lersten, N. R., & J. D. Curtis. 1977. Anatomy and distribution of secretory glands and other emergences in Tofieldia (Liliaceae). Ann. Bot. (London) 41:879-882. [Living plants of T. glutinosa from Emmet Co. were studied in most detail.]

McNeill, J. & W. G. Dore. 1976. Taxonomic and nomenclatural notes on Ontario grasses. Nat. Canad. 103:553-567. [Sphenopholis intermedia var. pilosa described as new and cited from St. Clair Co.]

Overlease, William R. 1975. Populations studies of red oak (Quercus rubra L.) and northern red oak (Quercus rubra var. borealis (Michx. f.) Farw.). Proc. Pennsylvania Acad. 49:138-140. [Studies along a gradient from Indiana to northern Michigan.]

Overlease, William Roy. 1975. A study of variation in black oak (Quercus velutina Lam.) populations from unglaciated southern Indiana to the range limits in northern Michigan. Proc. Pennsylvania Acad. 49:141-144.

Overlease, William R., & Edith D. Overlease. 1976. A study of spring herbaceous ground cover as an indicator of site conditions in mesic northern hardwoods, Benzie County, northwestern Michigan. Proc. Pennsylvania Acad. 50:173-178.

Schoen, Daniel J. 1977. Floral biology of Diervilla lonicera (Caprifoliaceae). Bull. Torrey Bot. Club 104:234-240. [Study of phenology, breeding system, and pollinators at Univ. Mich. Biological Station in Cheboygan Co.]

Schultz, Janet L. 1978. Bird consumption of scarlet elder fruit in Michigan's Upper Peninsula. Jack-Pine Warbler 56:3-7. [Contains ecological data on Sambucus pubens in Marquette Co.]

Smith, Edwin B. 1976. A biosystematic survey of Coreopsis in eastern United States and Canada. Sida 6:123-215. [Distribution maps show C. lanceolata in 6 Michigan counties, C. tripteris in 7, and C. palmata in 1; if the specimens in Univ. Mich. Herbarium had been mapped (they were allegedly examined, though not annotated), they would have added 11, 5, and 1 counties respectively—and one additional species, C. tinctoria.]

Solbrig, Otto T. 1971. The population biology of dandelions. Am. Sci. 59:686-694. [Includes data from experiments on Ann Arbor plants.]

Stephenson, Andrew G., & Wm. Wayt Thomas. 1978. Diurnal and nocturnal pollination of Catalpa speciosa (Bignoniaceae). Syst. Bot. 2:191-198. [Study done in Washtenaw Co.]

Vesper, Stephen J., & Ronald L. Stuckey. 1977. The return of aquatic vascular plants into the Great Lakes region after late-Wisconsin glaciation. pp. 283-299 in Geobotany (ed. Robert C. Romans), Plenum Publ. Corp., New York. [Maps of first occurrence records include Michigan sites for pollen of Nuphar and Myriophyllum.]

Werner, P. A. 1975. A seed trap for determining patterns of seed deposition in terrestrial plants. Canad. Jour. Bot. 53:810-813. [Includes data on seed dispersal in teasel, obtained in Kalamazoo Co.]

Werner, Patricia A., & R. Rioux. 1977. The biology of Canadian weeds. 24. Agropyron repens (L.) Beauv. Canad. Jour. Pl. Sci. 57:905-919. [Includes data from long-term field study of quack grass population dynamics in Kalamazoo Co.]

D. HISTORY, BIOGRAPHY, EXPLORATION

Crum, Howard. 1978. William Campbell Steere: An account of his life and work. Bryologist 80:662-694. [Fully illustrated, sympathetic, and readable account of an Ann Arbor native and one of the University of Michigan's most illustrious botanical alumni (later chairman of its Department of Botany). This volume of The Bryologist is dedicated to Dr. Steere on the occasion of his 70th Birthday and his retirement as President of the New York Botanical Garden; a fine color portrait is provided as a frontispiece.]

Jones, Kenneth Lester. 1977. Our botanical forbears in Michigan. Mich. Academ. 8:261-283. [Glimpses of selected eminent botanists active in Michigan before 1900: Thomas Nuttall, Douglass Houghton, Alexander Winchell, W. J. Beal, L. H. Bailey, Erwin F. Smith, Charles A. Davis.]

Robertson, Carol Kelly. 1976. Limnology in Michigan: An historical account. Mich. Academ. 8:185-202. [Capsule history, mostly of work at the University of Michigan, including the Biological Station, with emphasis on the direct and indirect influences of Paul S. Welch on teaching and research in this field.]

Voss, Edward G. 1978. Botanical Beachcombers and Explorers: Pioneers of the 19th Century in the Upper Great Lakes. Contr. Univ. Mich. Herb. 13. viii + 100 pp. $4.00 postpaid. [Illustrated account of the lives, explorations, and activities of about 150 persons and institutions, with bibliography of over 200 titles.]

–E. G. Voss

POLLEN ABORTION IN BETULA AND POPULUS (SECTION LEUCE)

Burton V. Barnes

School of Natural Resources
University of Michigan
Ann Arbor, 48109

Hybridization among species of birches *(Betula)* and also among aspens *(Populus)* is not uncommon in Michigan. Many of the putative F_1 hybrids–for example, between bigtooth aspen *(Populus grandidentata)* and trembling aspen *(P. tremuloides)* and between bog birch *(Betula pumila)* and yellow birch *(B. alleghaniensis)*–may be reliably distinguished from their parents by leaf and bud morphology. Nevertheless, due to substantial variation of leaves and buds within and among different individuals of a given species, identification is often surprisingly difficult, and putative backcrosses may be misidentified or overlooked if only leaf and bud characters are used. More reliable characters are needed. For many years I have used pollen irregularities (primarily pollen abortion) to distinguish and verify hybrid plants in *Betula* and *Populus.* The purposes of this paper, therefore, are to illustrate and describe how we have used and are applying pollen characteristics in attempting to identify various F_1 hybrids and backcrosses and to indicate how pollen abortion may be used as an index of the degree of hereditary relationships between different species.

Irregularities of pollen in certain angiosperms are useful for identifying hybrids and indicating evolutionary relationships among species. Hybrids between biological species often exhibit meiotic irregularities that are reflected in their pollen. These irregularities include high variation in grain size, abnormally formed grains, and aborted grains (primarily collapsed grains and rarely normally shaped grains that are completely void of cytoplasm). In F_1 hybrids of certain angiosperms, one finds abnormally large and small pollen grains. This causes a higher standard deviation in pollen diameter compared to pollen grains of the pure parent species. Also, aborted grains usually occur with greater frequency in hybrids than in parents. Because cytogenetic analyses of meiosis in populations of angiosperms are difficult and time consuming, studies of pollen abortion and variability of pollen diameter provide a reliable means of estimating the degree of hereditary relationship between divergent species. Furthermore, I have explored their use to identify hybrids and backcrosses as an aid to determining the amount of gene flow (intogression) between species of section Leuce of the genus *Populus.* The methods of pollen collection and handling are either described below or in the papers cited.

STUDIES IN BETULA

The reliability of pollen characters in *Betula* for reflecting meiotic behavior was demonstrated by Johnsson (1949). He studied both meiosis and pollen abortion in hybrids of the three artificial crosses: *B. verrucosa* X *B. japonica, B. verrucosa* X *B. papyrifera,* and *B. pubescens* X *B. papyrifera.* Hybrids of the two former crosses exhibited regular meiosis and normal pollen. Hybrids of the latter cross, however, exhibited "an entirely divergent course of meiosis with considerable disturbances" and great variation in pollen quality. Johnsson concluded: "Thus, the nature of the pollen in the three hybrids was found to be a true reflection of the meiotic course."

Using pollen characters we have examined the relationship of yellow birch (*Betula alleghaniensis*, 2n = 84) to three other North American birches, bog birch (*B. pumila,* 2n = 56), sweet birch (*B. lenta,* 2n = 28), and paper birch (*B. papyrifera,* 2n = 28, 56-84) (Table 1). Marked differences in pollen occur between the morphologically most divergent pair of birches, *B. alleghaniensis* (series Costatae) and *B. pumila* (series Humiles). The pollen diameter variation of the hybrid was twice that of either parent (Dancik & Barnes, 1972). The bog birch is also widely divergent from *B. papyrifera.* Clausen (1962) found the hybrid, *B.* X*sandbergii* Britton, had 42.0% aborted grains compared to 5.9% for *B. pumila* and 9.0% for *B. papyrifera.*

The close morphological relationship of *B. alleghaniensis* and *B. lenta* (both of series Costatae) is confirmed by studying the pollen of their hybrids (Sharik & Barnes, 1971) (Table 1). The 3.3% average abortion of the hybrid was not significantly different ($P > .10$) from the 2.5% of *B. alleghaniensis,* suggesting that meiosis of the hybrid was essentially regular. The coefficient of

TABLE 1. Comparison of diameter and abortion of pollen grains of North American birch species and their respective hybrids.

	Pollen Diameter (μ)			Aborted Grains (%)		
Species	Mean	Range	Standard Deviation	Mean	Range	Standard Deviation
B. alleghaniensis[1]	27.1	24.2-30.3	1.10	2.1	0.0- 8.5	1.67
B. pumila	21.5	19.8-24.1	0.80	0.6	0.0- 0.2	0.59
Hybrid	26.4	24.1-30.0	2.18	23.5	6.0-42.0	13.90
B. alleghaniensis[2]	30.9	28.4-32.9	1.20	2.5	0.0- 9.6	2.6
B. lenta	23.8	21.0-26.3	1.20	0.9	0.0- 3.0	0.9
Hybrid	27.6	25.3-30.0	1.10	3.3	0.0- 9.3	2.6
B. alleghaniensis[3]	27.1	26.0-33.8	1.70	1.7	0.0- 8.0	2.0
B. papyrifera	27.4	25.0-28.5	0.93	1.6	0.5- 4.0	1.1
Hybrid	28.7	26.2-31.0	1.73	2.4	0.0-10.0	3.4

[1] Source of comparison: Dancik & Barnes (1972); yellow birch population from southeastern Michigan.

[2] From Sharik & Barnes (1971); yellow birch population from New England.

[3] Source of comparison: Barnes et al. (1974); yellow birch population from Michigan.

variation of pollen diameter of the hybrid (7.7%) was in the normal range of values of the parent taxa, *B. lenta* (5.7%) and *B. alleghaniensis* (8.5%), lending additional support to this hypothesis. In addition, Santamour[1] found normal pairing of chromosomes at meiosis in one hybrid individual. Twenty-eight bivalents were present in all cells observed, and the pollen of this hybrid was normal. Of the 56 chromosomes in the hybrid, 42 came from *B. alleghaniensis* and 14 from *B. lenta.* Sharik & Barnes (1971) concluded that in the hybrid, chromosomes of two genomes (14 chromosomes each) of *B. alleghaniensis* pair autosyndetically with each other, and chromosomes of the third genome pair with the structurally homologous (homeologous) chromosomes of the genome of *B. lenta.* This would account for the low rate of pollen abortion and low variation observed in the hybrids.

B. alleghaniensis is less similar to *B. papyrifera* in several respects than to *B. lenta.* However, the studies of hybrids of *B. alleghaniensis* with *B. papyrifera* (Barnes et al., 1974; Table 1) suggest that these species also share similar genomes. Pollen abortion was low for the hybrids and variation in pollen diameter was negligibly different from that of the parents.

STUDIES IN POPULUS, SECTION LEUCE

We are currently analyzing pollen samples from clones of North American aspen species, *Populus tremuloides* and *P. grandidentata* and their hybrid, *P.* X*smithii.* We are also studying the relationship between these aspens and European species, *P. alba* and *P. tremula.*

Pollen samples of the native aspen species, F_1 hybrids, and backcrosses were collected from natural populations in southeastern Michigan and from a plantation at the University of Michigan Matthaei Botanical Gardens. The plantation contained pure species, F_1 hybrids, and backcrosses derived from open and controlled pollinations. Flower bearing branches were collected in early spring and brought into the greenhouse where the pollen was collected. The pollen was stained with acetocarmine in Hoyer's solution. Diameter measurements of 100 grains were made for most samples to determine pollen size and variation. The percentage of aborted grains (collapsed and non-staining grains) was determined from a sample of from 200 to 1500 grains for each clone. Sample size was typically 1000 grains.

P. tremuloides consistently exhibited the least variation in pollen diameter and abortion (Table 2). *P. grandidentata* was somewhat more irregular but generally was low in abortion and variation in diameter. F_1 hybrids exhibited a great range of sizes and many abortive grains, 20 to 30 times that of the parent species. Analyses of the 1966 data (Table 2) showed that clones of *P. tremuloides* from southeastern Michigan had significantly more aborted grains ($P < .05$) than pollen from northern Michigan, an area where natural hybrids between the species are rare. The presence of many

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[1] Written communication from Frank S. Santamour, Jr., U.S. National Arboretum.

TABLE 2. Pollen abortion percentage and pollen diameter for North American aspen species and hybrids of Section Leuce. Taxa designations: PT = *P. tremuloides*; PG = *P. grandidentata*; SEM = Southeastern Michigan; NLM = Northern Lower Michigan; TI = cross of PT Michigan X PT Idaho; TM = *P. tremuloides* from Manitoba, Canada; G X T = F_1 hybrid of PT X PG; GT X T = backcross to PT; GT X G = backcross to PG. GT - OP = open pollinated seedlings of F_1 hybrids; GT X GT = F_2 seedlings.

Taxa	No. of Clones	Collection Year	Abortion % Mean	Abortion % Range	Pollen Diameter (μ) Mean	Pollen Diameter (μ) Standard Deviation
PT – SEM	30	1966	2.7	0.0- 8.4		
PT – NLM	20	1966	1.3	0.0- 5.4		
PG – Michigan	25	1966	4.2	0.0-18.7		
PT – SEM	36	1974	2.4	0.0-10.0	31.2	2.88
PG – SEM	21	1974	3.9	1.0-14.1	30.3	3.12
PT	19	1975	1.1	0.3- 3.1	30.2	2.00
TI	4	1975	7.1	1.6-12.4	30.6	2.16
TM	2	1975	2.6	0.4- 4.8	32.9	4.50
PG	9	1975	1.6	0.4- 3.7	30.6	2.64
G X T	21	1975	23.6	5.1-35.4	30.6	3.32
GT X T	9	1975	11.3	1.4-21.6	30.6	3.16
GT X G	6	1975	11.5	0.5-25.5	29.1	3.21
GT - OP	7	1975	12.7	1.4-53.2	32.2	3.95
GT X GT	4	1975	28.5	15.5-36.9	32.2	4.74

natural F_1 hybrids and putative backcrosses in southeastern Michigan (Barnes, 1961; Andrejak & Barnes, 1969; Wagner, 1970; Henry & Barnes, 1977) suggested that the higher pollen abortion in southeastern Michigan compared with that in northern Lower Michigan might be partly due to hybridization and backcrossing. Backcrosses to *P. tremuloides* would probably have a higher pollen abortion percentage than pure *P. tremuloides* and in winter condition (when pollen was collected) might have been mistaken for the pure species. The pollen data reinforced morphological evidence (Barnes, 1961) suggesting that gene flow might be occurring between the species. Thus, the objectives of succeeding studies were to determine the usefulness of pollen abortion percentage and diameter variation in distinguishing hybrids and backcrosses and to use these reproductive characters in determining how much gene flow, if any, was occurring between the species.

In 1974, pollen was again collected from randomly selected, naturally occurring clones of *P. tremuloides* and *P. grandidentata* in southeastern Michigan (Table 2). Average pollen abortion was 2.4% for the former species and 3.9% for the latter. Some of the clones with high values (from 5% to 14%) may be backcrosses; foliage and buds of these clones would have to be collected to help determine their identity. However, if a standard or baseline value of abortion rate and pollen diameter variation for pure *P. tremuloides* and *P. grandidentata*, F_1 hybrid, first generation backcross, etc., could be determined, these pollen traits might be more reliable in distinguishing hybrids and backcrosses (and in assessing the amount of gene flow) than morphological characters.

To provide such baseline pollen data, a series of controlled crosses among species and hybrids was made in 1968. The seeds from these crosses were sown in 1968, and seedlings were outplanted in 1969 at the University of Michigan Botanical Gardens. In addition, open pollinated seeds from several sources of *P. tremuloides, P. grandidentata,* and F_1 hybrid clones were collected, sown, and the seedlings also outplanted in 1969.

Pollen from seedlings of these taxa, at age seven years from seed, show that the parents and hybrids are markedly different in pollen abortion and diameter variation. F_1 hybrids from controlled pollinations averaged 23.6% aborted grains whereas *P. tremuloides* and *P. grandidentata* averaged 1.1% and 1.6%. The standard deviation of pollen diameter of F_1 hybrids was significantly higher than that for *P. tremuloides* ($P < .01$). Seedlings of crosses of female *P. tremuloides* of southeastern Michigan with a clone of *P. tremuloides* from northern Idaho had a higher abortion rate. This suggested genetic differences among eastern and western populations.

Backcrosses to *P. tremuloides* (GT X T) and *P. grandidentata* (GT X G) exhibit 11.3% and 11.5% abortion, or approximately half that of the F_1 hybrids. However, several backcross individuals lie within the range of the recurrent parent species or that of the F_1 hybrid. Although data from more clones are necessary to refine the relationship, it appears that many backcrosses can be distinguished using pollen abortion and pollen diameter data.

Seedlings from open-pollinated hybrids (GT-OP) exhibited 12.7% aborted grains, again nearly one-half of the hybrid value. The average is misleading, however, since nearly all individuals had abortion percentages within the range of the parents or that of the F_1 hybrid. More individuals will need to be investigated to define more precisely the distribution of the abortion values. Thus, it appears that due to individual tree variation pollen abortion data, although useful in population studies, cannot in itself be used to distinguish conclusively individual first generation backcrosses from the parent species or F_1 hybrids. However, the distinction could probably be made by combining abortion data with key morphological features.

For all clones in the 1975 collection (Table 2) pollen abortion percentage was significantly and moderately strongly correlated with the standard deviation of pollen diameter ($r = 0.63$).

Preliminary comparative studies of pollen of European species and hybrids indicate that *P. tremuloides* and *P. tremula* (European aspen) are very closely related. The pollen abortion of hybrids between them was low. Samples from two populations of the hybrid showed average abortion percentages of 2.5 (38 individuals) and 4.4 (28 individuals). Eighty-two percent of the individuals of the hybrids of the combined populations were within the normal range of the abortion percentage of *P. tremuloides* (0-3%). The pollen diameter was relatively uniform. In contrast, hybrids of *P. grandidentata* and *P. tremula* exhibited high abortion percentages (up to 24%) and a variable pollen diameter. Hybrids between *P. grandidentata* and *P. alba (P. rouleauiana)* and *P. tremuloides* and *P. alba (P. heimburgeri)* exhibited pollen abortion percentages between 6 and 26. The average of two *P. alba* hybrids *P. tremuloides* was 13%; the average for 20 *P. alba* hybrids with *P. grandidentata* was 15%. Based on these limited data it is premature to say which of the North American species is more closely related to the European white popular, *P. alba.*

SUMMARY

Studies were conducted in *Betula* and *Populus* (Section Leuce) using pollen irregularities (abortion percentage and variation of pollen diameter) to elucidate relationships among species. In *Betula,* pollen abortion of interspecific hybrids appears to be a reliable indicator of species relationships. Hybrids of *Betula alleghaniensis* with *B. lenta* and *B. papyrifera* exhibited low abortion percentages and diameter variation; a close relationship was indicated. Hybrids of *B. alleghaniensis* with *B. pumila*, however, exhibited many aborted grains and a variable pollen diameter; these species are not closely related.

In *Populus,* F_1 hybrids derived from controlled pollinations between *P. grandidentata* and *P. tremuloides* exhibited high abortion percentages (average of 24%) whereas the abortion of the pure species was only 1 to 2%. Abortion percentage and standard deviation of pollen diameter were significantly correlated ($r = 0.63$). The wide difference in abortion percentage among the F_1 hybrid and the parents provides a basis for identifying backcrosses to either species and presents the possibility of using abortion percentage as an index of the amount of gene flow between the species. The average abortion percentage of backcrosses to either parent was about half that of the F_1 hybrids. However, individual variation of the backcrosses in abortion percentage was great, often overlapping that of the parents and the F_1 hybrids. In identifying putative naturally occurring backcrosses, pollen abortion must be used with great caution and in conjunction with morphological characters.

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COMPARISON OF ROOTS AND STEMS OF ALFALFA SEEDLINGS GROWN ON SOIL AND COPPER TAILINGS

Patricia A. Dean and Frederic H. Erbisch

Department of Biological Sciences
Michigan Technological University
Houghton, 49931

Among the remnants of the copper mining industry in Houghton and Keweenaw Counties, in Michigan's Upper Peninsula, are large deposits of tailings. These tailings dumps are sometimes in the form of fine sand-like particles that are dispersed into nearby areas by winds and are considered to be a nuisance. In an effort to rectify this situation, growing vegetation on some tailings deposits was attempted. Numerous types of plants, including grasses, alfalfa, willows, and tomatoes, in a variety of experiments, were used as means of vegetating the tailings (Erbisch, 1974, also unpublished data; Shetron & Ritter, 1973, also unpublished data). In all cases it was found that something in the tailings inhibits normal plant growth and development. Comparative studies (Weidner, 1976; Erbisch, unpublished) noted significant differences in protein content and copper accumulation in the roots of tailings- and soil-grown plants. However, it was not known if the cellular and tissue structure of the plants was affected. Consequently, a comparative study of the anatomy of roots and stems of alfalfa grown on tailings and soil was undertaken.

Tailings were obtained from an area called the Tamarack Sands near Hubbell, Michigan. Tailings from the same deposit had been used in earlier experiments (Erbisch, 1974; Weidner, 1976). Seeds of alfalfa (*Medicago sativa*) obtained locally were planted in containers on soil and tailings. Approximately one gram of seed was placed in each container, four containers were used, and the experiment was repeated. The seeded containers were placed in a growth chamber (18°C, 14 hr. day; 12°C, 10 hr. night), moistened periodically with de-ionized water, and harvested 21 days after germination. Root and stem pieces (25-50 of each set) were placed in Nawaschin fixative, dehydrated in tertiary butyl alcohol, embedded in paraffin, sectioned at 7 μ, and stained in saffranin and fast green. Other root pieces were critical-point dried and coated with a mixture of gold and palladium for examination with a JEOL model JSM U-3 scanning electron microscope using a 25-kv accelerating voltage.

It was found that root and stem diameters of tailings-grown plants were smaller than those of soil-grown plants. Tailings-grown plants had an average root diameter of $253 \pm 68\,\mu$ one centimeter from the tip and a stem diameter of $505 \pm 86\,\mu$ one centimeter from the soil line. The average diameters in soil-grown plants were $542 \pm 44\,\mu$ for roots and $687 \pm 34\,\mu$ for stems. Transverse sections showed that cellular differentation of tailings-grown plants was considerably less than that of soil-grown ones. Tailings-grown plant cells appeared to be less developed than soil-grown ones. Differences were particularily evident in root sections which showed cortical cells more compact, with less vacuolar development, and more deeply stained in tailings plants than in soil plants. The most notable difference was in root stelar structure. Tailings-grown plants had a one- to three-armed, poorly differentiated xylem, while the soil-grown ones consistently had four-armed, well developed xylem (Figs. 1 & 2). Xylem cell shape and wall thickness also varied more in the roots of tailings-grown plants than soil-grown ones (Fig. 3). In stems the cells of tailings-grown plants, like those of the root, were more compact and deeply stained than those of soil-grown plants. Cell walls of the stem parenchyma in tailings-grown plants appeared to be quite fragile, as they were consistently fractured on sectioning, whereas those of soil-grown plants were not broken. Stelar configurations of tailings- and soil-grown stems were similar. Cells of the xylem were smaller in the tailings-grown stem material than those of the soil-grown stems. Xylem cell wall differences were not seen.

In addition to the differences noted, SEM examination disclosed variations in numbers of root hairs—scarce or non-existent on tailings-grown plants, but abundant on soil-grown ones (Figs. 4 & 5).

The striking anatomical differences in root xylem and root hair formation between tailings- and soil-grown alfalfa plants would seem to

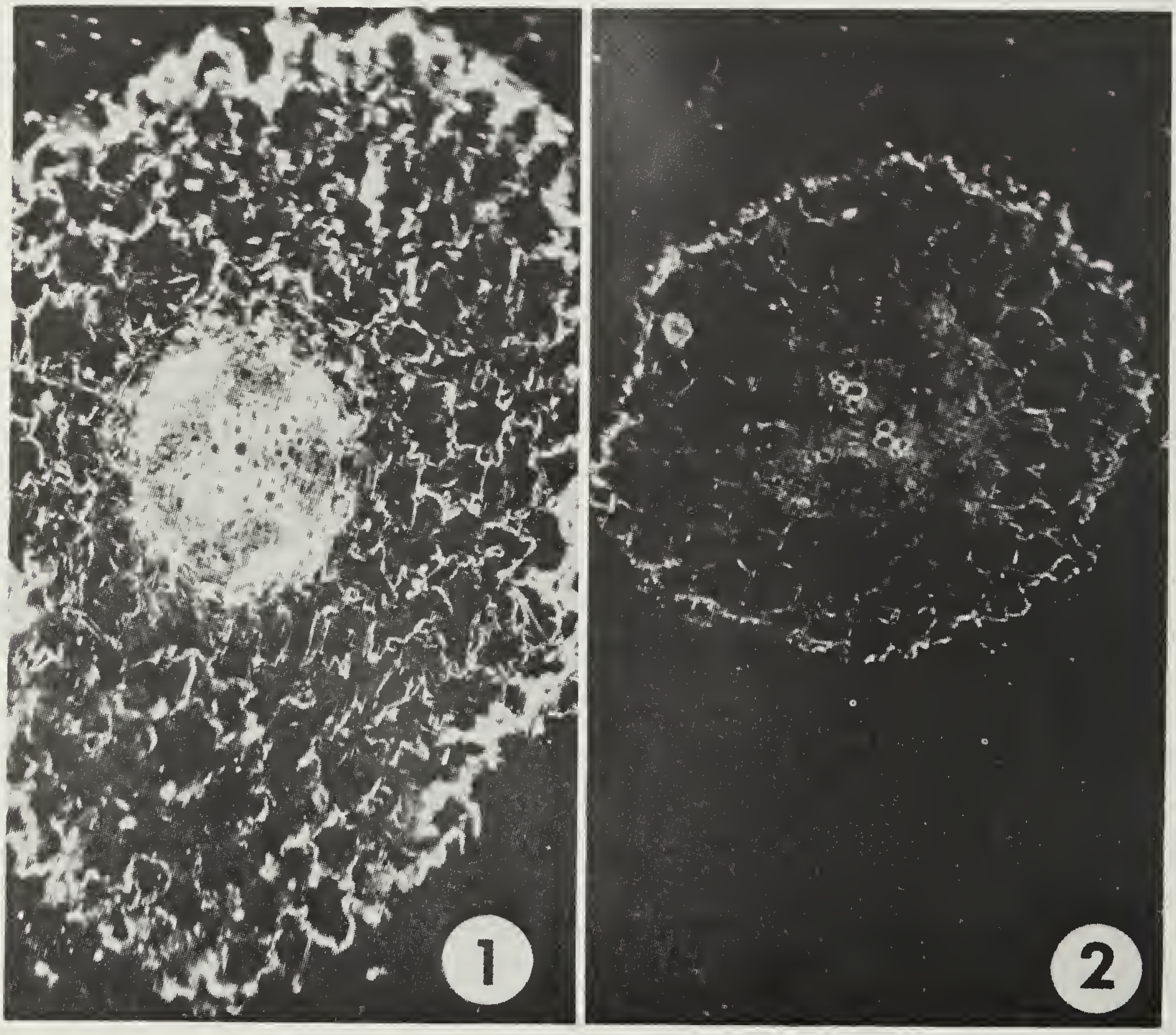

Fig. 1. Transverse section of a root of a soil-grown alfalfa seedling (×100, darkfield microscopy). Fig. 2. Transverse section of a root of a tailings-grown alfalfa seedling (×100, darkfield microscopy).

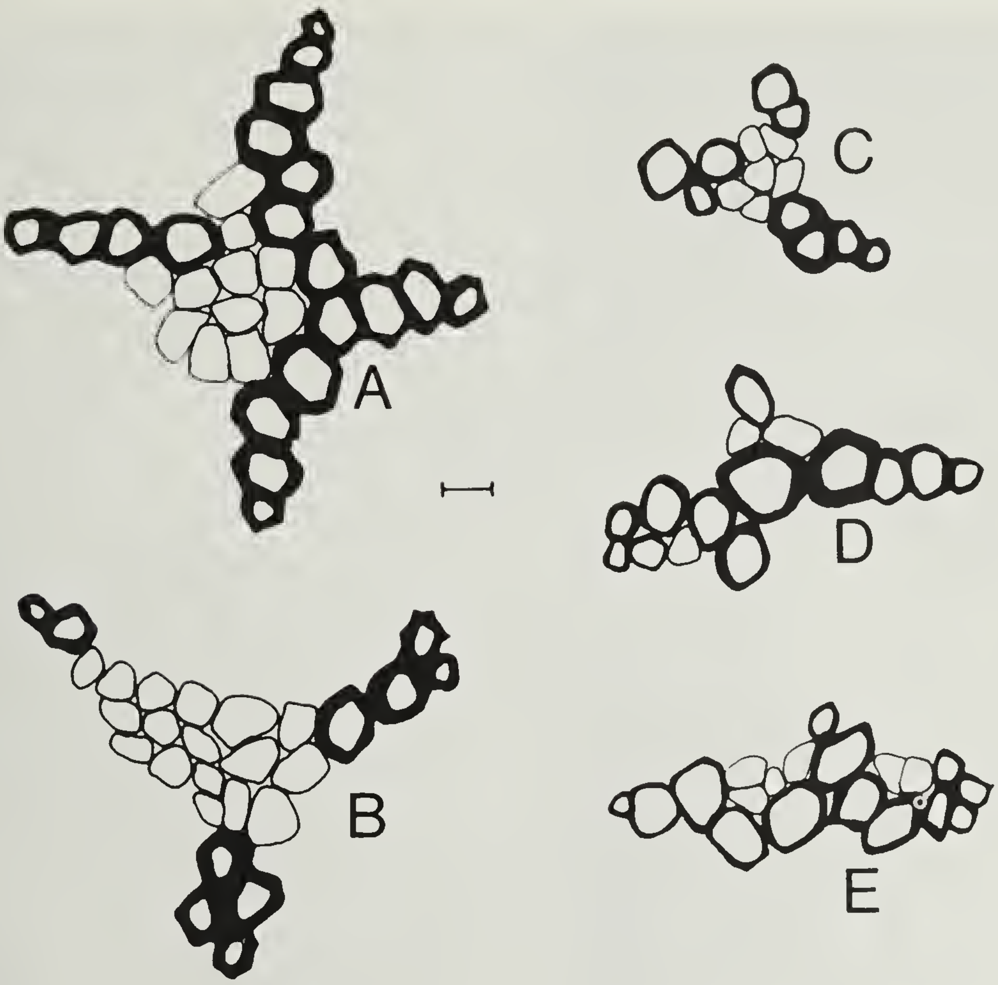

Fig. 3. Root xylem configurations of soil- and tailings-grown plants. A-B. Soil-grown plants with normal 3- and 4-armed xylem. C-E. Tailings-grown plants with abnormally formed steles. The scale line = 10 μ.

account for the poor growth of plants on tailings. The absence or scarcity of root hairs would be detrimental by reducing absorption of water and nutrients. Likewise the poor root xylem formation would adversely affect translocation from the root to the stem and leaves. The more compact, fragile cells, seen in the aerial portion of tailings-grown seedlings could be a result of impaired transport of nutrients depriving the stem of essential elements. Plants with impaired water and nutrient uptake and transport would also have great difficulty in maintaining themselves on the tailings (Shetron & Ritter, 1973).

In this series of experiments neither the seeds nor growth conditions can be considered responsible for the anatomical differences noted. All seeds came from the same seed lot, and all plants were grown under the same controlled conditions. Therefore, the differences must be caused by some factor in the tailings. This tailings factor either directly or indirectly affects root development.

Luxová (1975) indicated that the root primordium of *Zea mays* is histologically determined by the time of embryo maturation. A change in the pattern of stelar development was attributed to changes in frequency of cell division and the orientation of division walls reflecting physiological conditions of the meristematic region (Luxová, 1975; Torrey, 1957). If radicals of alfalfa embryos are histologically determined before germination, then the "tailings factor" would not alter the stelar structure directly. The

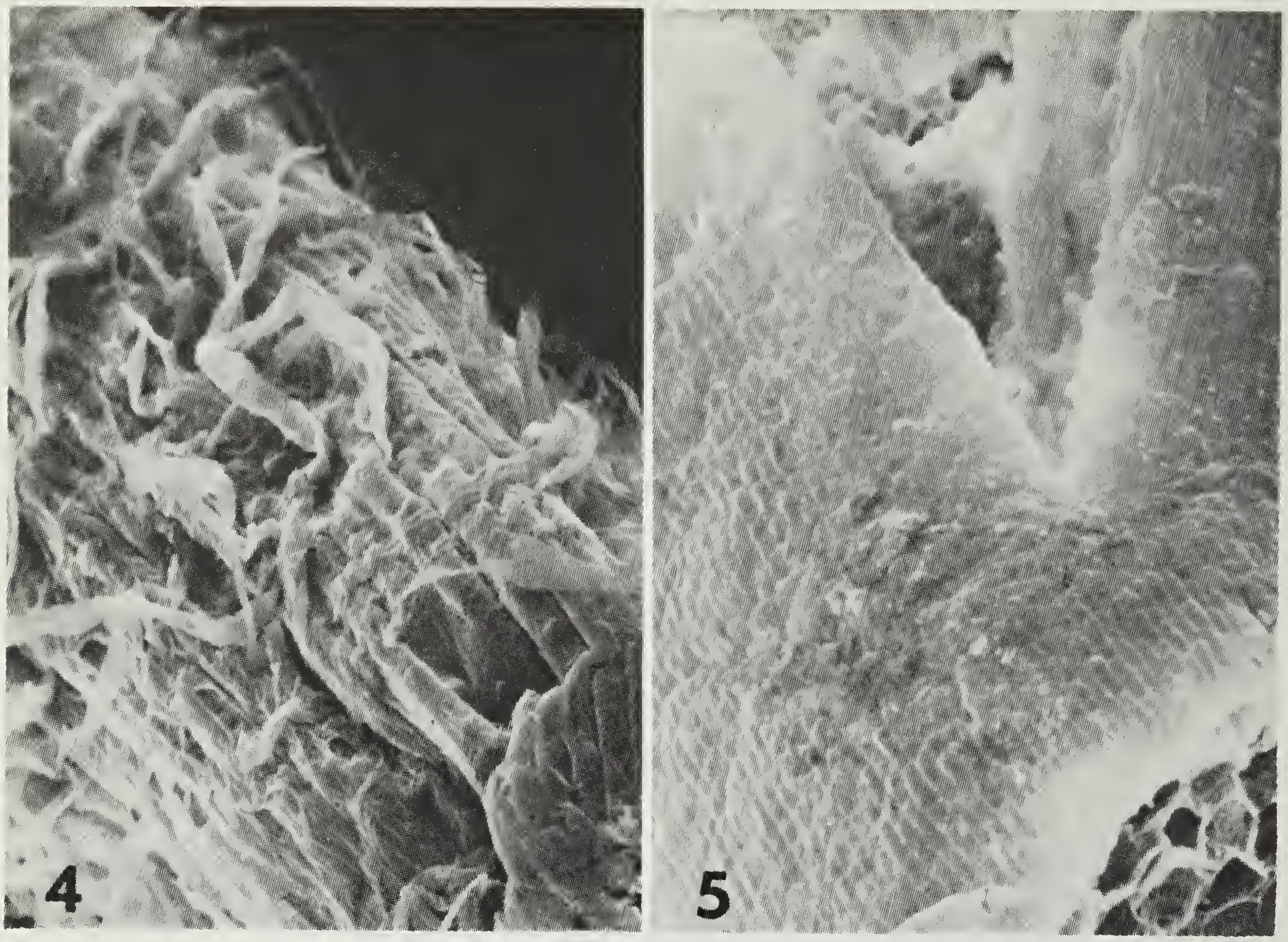

Fig. 4. Scanning electron micrograph of a portion of a root surface from a soil-grown plant (X100). Note abundance of root hairs. Fig. 5. Scanning electron micrograph of a portion of a root surface from a tailings-grown plant (X100). No root hairs were found on this specimen.

alfalfa stelar variations were due to an indirect effect of the "factor", perhaps through a variation in protein composition (Weidner, 1976).

While the "tailings factor" has not been isolated, evidence strongly suggests that it may be copper. Tailings-grown roots have a higher copper concentration than soil-grown ones (Weidner, 1976). Struckmeyer *et al.* (1969) found anatomical disorders in tobacco roots grown in excess copper solutions. Walls of the xylem were thin and misshapen, and there was less vascular tissue differentiation than in normal roots. Bennett (1974) stated that "symptoms are usually not sufficiently unique to identify Cu toxicity without the knowledge that possible excessive Cu is present in the growth medium." Large concentrations of copper exist in the tailings, up to 2000 ppm (Erbisch, 1974), but the availability of this element to plants is unknown. It exists in metallic form, as pure copper, and is not complexed with other elements, and the high pH of the tailings, 8.3 (Erbisch, 1974), prevents its solubilization.

SUMMARY

Copper tailings-grown alfalfa seedlings showed poor root development when compared to soil-grown ones: root hairs did not develop, nor was xylem formation normal. Such poor development may be caused by some unknown factor in the tailings, perhaps copper. Differences in stem development, cell size and cell wall strength, are attributed to the poor root development rather than to the "tailings factor".

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NATHAN WRIGHT FOLWELL, ASA GRAY'S BOTANICAL CORRESPONDENT IN MICHIGAN

Ronald L. Stuckey

Department of Botany, College of Biological Sciences,
Ohio State University, Columbus, 43210

Over the past several years knowledge of Michigan pioneer botanical collectors and their contributions has been increasing. Papers have been prepared on early floristic work in northern Michigan (Voss, 1956), Thomas Nuttall's expedition into the Old Northwest in 1810 (Stuckey, 1967), David Bates Douglass' plants from the Cass Expedition in 1820 (Stuckey, 1978), the botanical collections obtained in Michigan from the Schoolcraft Expedition in 1832 (Rittenhouse & Voss, 1962), the botanical results of the Michigan Geological Survey involving Dr. Douglass Houghton, Dr. John Wright, and Dr. Abram Sager in 1837-1840 (McVaugh, 1970), and on an exploring expedition concerned with the botany, forestry, and agriculture of the northern portion of the Lower Peninsula of Michigan (Voss & Crow, 1976). This short paper brings together a few scattered and seemingly unrelated notes from botanical literature which identify an early Michigan botanical collector, Dr. Nathan Wright Folwell, who appears to be the first contributor to Asa Gray's herbarium.

While searching through the herbarium of the Academy of Natural Sciences of Philadelphia on several extended research visits there within the past 12 years, I have located several specimens[1] that bear labels with the locality "Michigan" or the combination of "Michigan" and the name of a collector or donor, "Gray." Without knowing the story that is developed in this paper, one might suspect that the collections were obtained by Dr. Asa Gray when he visited the state of Michigan in 1838 for the purpose of investigating the campus and the offered position as Professor of Botany in the newly founded University of Michigan (Bartlett, 1941; Dupree, 1959). Some of the labels with the specimens were prepared by Asa Gray in his handwriting; others were written by Dr. Charles Pickering[2] who identified them as once belonging to the herbarium of Schweinitz.

Rev. Lewis David von Schweinitz was one of the well-established botanists on the east coast, at Bethlehem, Pennsylvania. His herbarium of some 23,000 species of vascular plants resulted from his own collections and from exchange with some 108 contributors (Pennell, 1935). One of his correspondents was the young Asa Gray, who lived at Utica, New York, where he taught science in Bartlett's Utica Gymnasium. At 21 years of age, Gray was just beginning to collect plants and to exchange specimens with learned and active botanists. His correspondence with Schweinitz is known to consist of two letters, one dated 15 November 1832 and the other 8 March 1833. The correspondence probably would have continued, but Schweinitz died 8 February 1834. In the first letter Gray explained that he was sending a parcel of plants and desired to know what plants Schweinitz wanted so that he (Gray) could lay in a good supply next summer. In the second letter, Gray (1833) wrote about a *Carex* that Schweinitz named for Gray, sending a small package of plants, and certain plants thát Gray had collected at Oneida Lake, Niagara Falls, or the New Jersey Pine Barrens. Then he said:

> I have lately received some good plants from Michigan Ter. such as Carex longirostris (very old) Koeleria orthostachya Tor. *ined.*Tofieldia glutinosa Mx. Houstonia tenerifolia *Nutt*? Euonymus atropurpureus, Lythrum hyssopifolium, Hydrophyllum appendiculatum, Monarda ciliata var. *Potentilla confertiflora* one specimen (I expect more) &c. all of which will find a place in my next package. I find my ardor for Botany increasing rapidly, and I mean to collect very extensively the ensuing spring and summer. . . . (quoted from Shear, 1905).

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[1] Specimens from the Schweinitz Herbarium at the Academy of Natural Sciences, Philadelphia (PH).

With labels in the handwriting of Asa Gray: "Carex buxbaumii Wahl Michigan Ter[ritory]."–"Carex hirsuta Michigan Ter[ritory]" = *C. hirsutella* Mackenzie.

With labels in the handwriting of Charles Pickering: " '(herb Schw) Betula pumila vel B. glandulosa in Michigan–Gray' " = *B. pumila* L. – " 'Carex squarrosa Michigan Gray'."–" 'Lythrum hyssopifolium Detroit–Gray'." The specimen is *Lythrum hyssopifolium.* However, this species, non-indigenous to North America, has never been reported for Michigan. The specimen may represent a "waif" or one whose label has been interchanged with some other specimen.

[2] Curator of the Academy Herbarium from 1827 to 1838 (Pennell, 1942).

Gray does not identify his Michigan correspondent in this letter, nor does Schweinitz (undated) identify him throughout his unpublished Systematically Arranged Catalogue of Plants, in the list of the 108 contributors in the front of the book, or on any of the herbarium specimens that have been located. Schweinitz's herbarium was bequeathed to the Academy of Natural Sciences, where it is today. Among those taxa listed in Gray's letter to Schweinitz, only the *Lythrum* was recovered in the Academy herbarium.

About this same time, in the winter of 1831-32, Gray began correspondence with Chester Dewey, clergyman and scientist of many interests then living in Pittsfield, Massachusetts, where he taught a high school for boys (Dupree, 1959, p. 29). Dewey was interested in *Carex* and published his research in a series of papers under the title "Caricography" in the *American Journal of Science.* In giving the habitat and locality information for *Carex decomposita,* Dewey (1833) wrote, "Found abundantly by Dr. Folwell in a swamp near the river Raisin, in Michigan Territory, and sent to Dr. Gray of Utica, N.Y., who has obligingly sent me specimens." This reference and the coincidence of dates and place (Michigan) seem sufficient to establish that Gray's Michigan correspondent was Dr. Folwell.

Dr. Folwell's name is known to appear in two other botanical publications. He is listed as the collector of the specimen of *Koeleria cristata* included in Part 1 of Gray's exsiccata of *North American Gramineae and Cyperaceae* (1834). The specimens used to represent this species were sent by Dr. Folwell late in the summer of 1834, as acknowledged by Gray in a letter dated 4 October 1834, where he wrote, "I thank you . . . for the supplies of some valuable grasses, especially for the fine lot of *Koeleria cristata,* which I very much needed." This grass specimen appears as no. 45 in the *exsiccata* with the locality information, "Michigan Territory." Reference to this collection was made by McVaugh (1968) in a paper on rare old publications in Michigan herbaria.

In Torrey and Gray's *Flora of North America* (1838-43, vol. 1, p. 13), Dr. Folwell is given as the contributor of a specimen of *Anemone cylindrica* from Michigan. This notation is apparently the only place in the entire flora where he is mentioned. His name was not listed in the preface where Torrey and Gray acknowledged many of the contributors of specimens. Ewan (1969) was unable to identify or supply any additional information about Dr. Folwell in his *Introduction* prepared for the facsimile reprint edition of Torrey and Gray's *Flora.*

Dr. Folwell's personal herbarium of plants collected in 1831 and 1832 was presented to the Wiegand Herbarium of Cornell University, 20 September 1935, by Mrs. Thomas Folwell Cole of Romulus, New York. While on a brief visit to the Wiegand Herbarium in the summer of 1973, I noted the labels on five specimens.[3] In addition to the printed labels identifying the collector, donor, and date of presentation, Folwell's original handwritten labels were also intact on the sheets. The plants examined were collected by Dr. Folwell in Michigan Territory in Monroe and Lenawee counties during June and July of 1832. Duplicates of three of these collections are known to be in the Herbaria of Harvard University. Additional investigation in the Wiegand Herbarium may reveal other localities where Folwell obtained plants in the southeast corner of Michigan. That printed labels were prepared and added after the collection came to Cornell University is an indication that an "ample" number of specimens must have been involved in the transaction.

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[3] Herbarium records seen in the Wiegand Herbarium at Cornell University (CU) are cited below, in addition to some records from other herbaria (AMES, GH, NY). Data from the latter herbaria were extracted from the files of the Michigan Flora Project under the direction of E. G. Voss, University of Michigan, Ann Arbor. The data are not quoted,

According to Dupree (1959), Dr. Folwell was a classmate with Asa Gray at the College of Physicians and Surgeons of the Western District of the State of New York at Fairfield. After graduation in January 1831, Gray became particularly fascinated by Botany, and eventually gave up his potential medical career for science. In a letter of 14 March 1831, Gray urged his friend, Dr. Folwell to "collect plants like the Devil and all–. I expect you to bring 150 species at least . . ." (Dupree, 1959, p. 22). Gray spent a week or two in late summer of 1831 collecting with Dr. Folwell at Lodi in Seneca County, New York (Dupree, 1959, p. 23). In a letter of 6 April 1832 to Dr. John Torrey, botanist in New York City, Gray referred to Folwell as "an industrious collector" (J. L. Gray, 1893, p. 35). Often addressed as "my chum," Dr. Folwell was undoubtedly a close personal friend of Gray's and from the account in Dupree (1959), it appears that Folwell was among the first whom Gray interested in botany and also believed to be the first person who contributed to Gray's herbarium.

The circumstances and events that took Dr. Folwell to the Michigan Territory are yet to be learned. His stay must have been of short duration, probably confined to the summer of 1832 for soon after receiving his Medical Degree in January 1832, he entered into the practice of medicine in his home county and in March 1833 was appointed as a hospital surgeon in the state of New York.

As summarized from Bellows (1926), Nathan Wright Folwell was born 27 December 1805 at Southampton, Bucks County, Pennsylvania, to William W. and Jane (Dungan) Folwell, of English and Scotch-Irish descent, respectively. In June 1807, he moved with his parents to the town of Romulus, New York, and spent his early life on a farm owned by his father on the east shore of Seneca Lake, midway between Willard and Dey's Landing. His education came by attending the district schools, a private school at Lodi, New York, and the college at Geneva, now Hobart College, from

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but summarized from the various herbaria: *Betula pumila* L. Michigan Territory, Lenawee Co.: Wet prairie, July 1832, CU.–*Carex buxbaumii* Wahl. Michigan Territory: Woods, June 1832, CU.–*Carex decomposita* Mulh. Michigan Territory [Monroe Co.?]: Low wet swamps, June 1832, CU, GH, NY.–*Cypripedium reginae* Walt. Michigan Territory [Monroe Co.]. Low ground, sand border of River Macon, June-July 1832, AMES, CU.–*Habenaria ciliaris* (L.) R. Br. Michigan Territory [Monroe Co.]: Sandy soil, low ground, oak openings, July 1832, AMES, CU.

which he graduated in August 1828. He then studied medicine in Townsendville under Dr. C. C. Coan, and in September 1829 entered the College of Physicians and Surgeons of the Western District of the State of New York at Fairfield, where he took his medical degree in January 1832, a year later than did Asa Gray. Soon after leaving Fairfield, he entered into the practice of medicine with Dr. Coan in the town of Lodi. Dr. Folwell was appointed hospital surgeon of the Fifth Brigade of Cavalry of the State of New York in March 1833 and to a similar position of the Third Division of Cavalry in September 1837. On 7 May 1834, he married Caroline Reeder of Trenton, New Jersey; they became the parents of 10 children. In 1840, he dissolved his partnership with Dr. Coan and moved to North Hector, Schuyler County, where he remained until 1849 when failing health compelled him to relinquish his practice. He removed to the old homestead at Romulus, where he remained briefly, and then purchased about 200 acres of land, which he improved for agriculture. He resided on this farm until his death, 4 February 1879.

According to Bellows (1926), as a physician, Dr. Folwell "ranked with the best in the community where he so long resided. As a citizen he was esteemed for his enterprise and as a Christian man he was earnest, active, benevolent and was public spirited to a large degree, always actively engaged and interested in the affairs of the church . . ." Concerning his botanical activity, Bellows noted that "Dr. Folwell was always an enthusiastic student of botany, and in the pursuit of this study joined his devoted and life-long friend Prof. Asa Gray, . . ." Dr. Folwell must be regarded as one of the first individuals Asa Gray interested in the study of plants and evidently the first in a succession of numerous contributors to Gray's herbarium and his development into the foremost nineteenth century North American botanist.

The research presented here resulted principally from two extended periods at the Academy of Natural Sciences, Philadelphia, sponsored by a National Science Foundation grant to the Academy in 1973 and by the Academy in 1977. The paper was read to the Historical Section of the Botanical Society of America at the American Institute of Biological Sciences meeting at Michigan State University, East Lansing, 23 August 1977.

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THE DISTRIBUTION OF THE AQUATIC VASCULAR FLORA OF DOUGLAS LAKE, CHEBOYGAN COUNTY, MICHIGAN[1]

Robert R. Haynes
Department of Biology
University of Alabama
University, 35486

C. Barre Hellquist
Dept. of Biology
Boston State College
Boston, 02115

Recently, much concern has been devoted toward the continual deterioration of water quality in the natural lakes of the United States. Carlson (1977) has compiled a trophic state index for lakes based upon chlorophyll *a* concentration. Gannon (in correspondence) has applied this index to 44 lakes in northern Michigan and has concluded that although most of the larger lakes do receive some effluent from septic tanks, in general those lakes with a relatively large flow and quick turnover are not in any immediate danger. For example, he considers Douglas Lake, Cheboygan County, to be in a state of mesotrophy with ca. 6 micrograms/liter of chlorophyll *a*. Bazin and Saunders (1971), on the other hand, considered a gradual increase in the rate of oxygen depletion below the thermocline to be an indicator of eutrophication. They detected an apparent trend in Douglas Lake of a more rapid depletion rate. They, therefore, concluded that Douglas Lake is slightly eutrophic.

Regardless of whether we consider Douglas Lake mesotrophic or slightly eutrophic, we should be concerned with the possible effects of continued (especially increasing) eutrophication upon the physical and biological aspects of the lake. Before these effects can be adequately understood, one must have a thorough description of the physical and biological components of the lake. Personnel at the University of Michigan Biological Station (UMBS) have been studying Douglas Lake for nearly 70 years, and a considerable amount of data has been compiled. For example, the morphometry of the lake has been described by Scott (1921), Welch (1927), and Wilson (1945). Gannon & Brubaker (1969), Gannon & Fee (1970) and Tallman (1975) have described the seiches and circulations in the lake.

The biota, however, have not received such thorough treatment. Moffett (1943) and Neel (1948) studied the biota of Big Shoal, concerning themselves mostly with invertebrates and non-vascular plants. Other individual groups have been examined in the lake. Tucker (1957) worked on the ecology of phytoplankton, and Reighard (1915) studied habitats of the fishes. Published studies on the aquatic flowering plants include Bromley (1967) on the spreading of aquatic flowering plants in deep water, Williams (1970) on the morphology of the water lillies (*Nymphaea*), and Weber (1972) on the importance of turions in *Myriophyllum* reproduction. However, no comprehensive list of either the flora or fauna has been published for Douglas Lake. It is our objective to prepare such a list for the aquatic vascular plants.

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[1] Paper No. 3 from Aquatic Biology Program, University of Alabama. Field work was carried out at the University of Michigan Biological Station where the senior author was a faculty member and the junior author a teaching assistant.

Douglas Lake, occupying 1509.36 hectares and with a maximum depth of 27.1 meters, maximum length of 6.10 km and maximum width of 3.64 km, is a thermally stratified lake in which the hypolimnion is warm. The lake has a yearly Secchi disc range of 3.0-4.5 m, total alkalinity (as $CaCO_3$) of 115.3, specific conductance (µmhos/cm corrected to 25° C) of 249.5, and pH of 8.5. The latter three parameters are summer data taken during 1973 and 1974. All physical data are from Gannon (personal correspondence). According to Humphrys & Greene (1965), the shore is 98% mineral and 2% organic. The lake has one major inlet, Bessey Creek, plus four smaller ones, and one main outlet, Maple River.

Sampling was conducted in Douglas Lake at 43 localities (Fig. 1). Except as noted below, all the sampling localities cover an area from the shore outward into the lake until the water is too deep for plants to grow. Each site covers a distance along the shore and water halfway from the preceding halfway to the next site. Therefore, we have covered

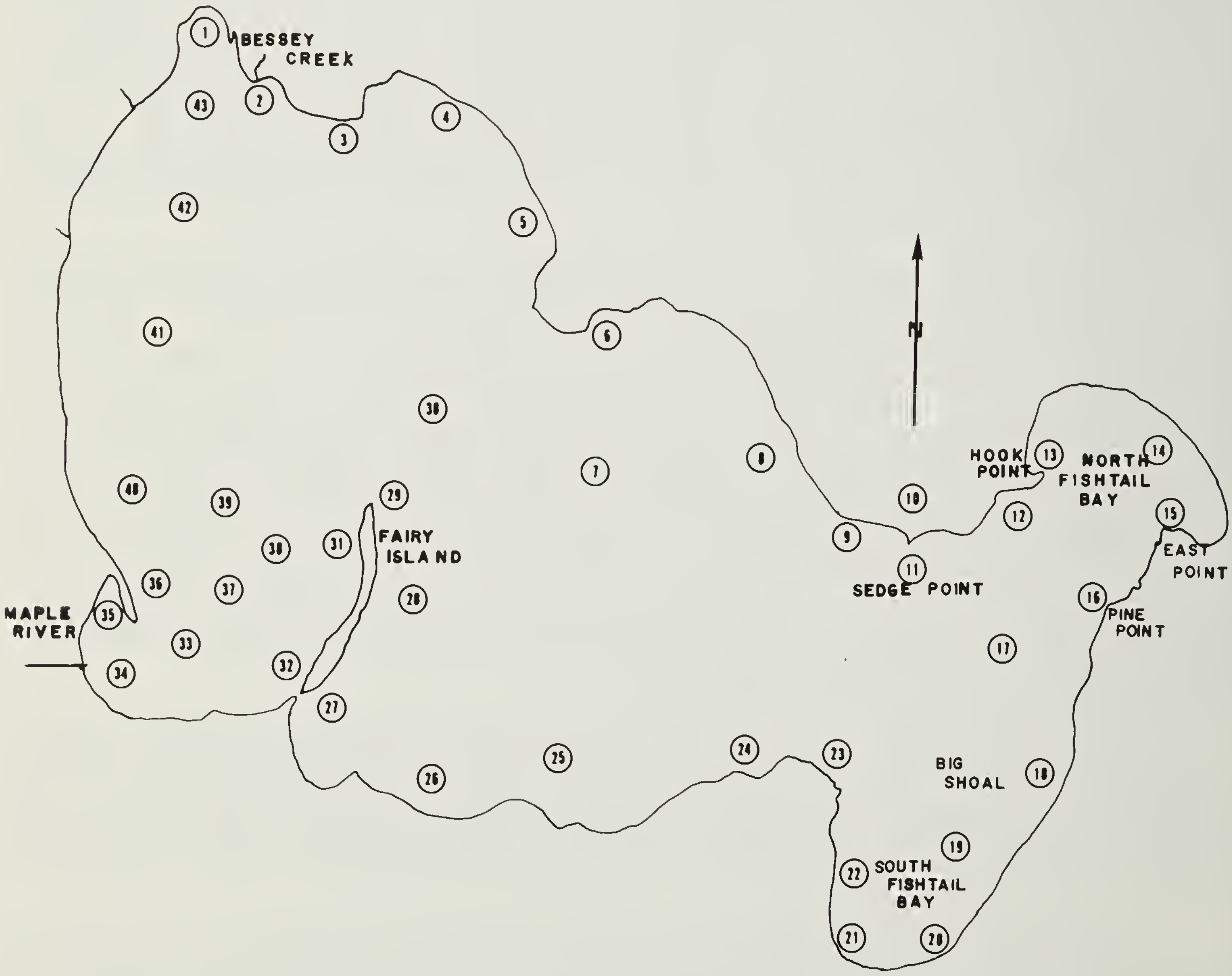
BESSEY CREEK
FAIRY ISLAND
MAPLE RIVER
N
HOOK POINT
NORTH FISHTAIL BAY
EAST POINT
SEDGE POINT
PINE POINT
BIG SHOAL
SOUTH FISHTAIL BAY
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Fig. 1. Douglas Lake with collecting localities indicated by number.

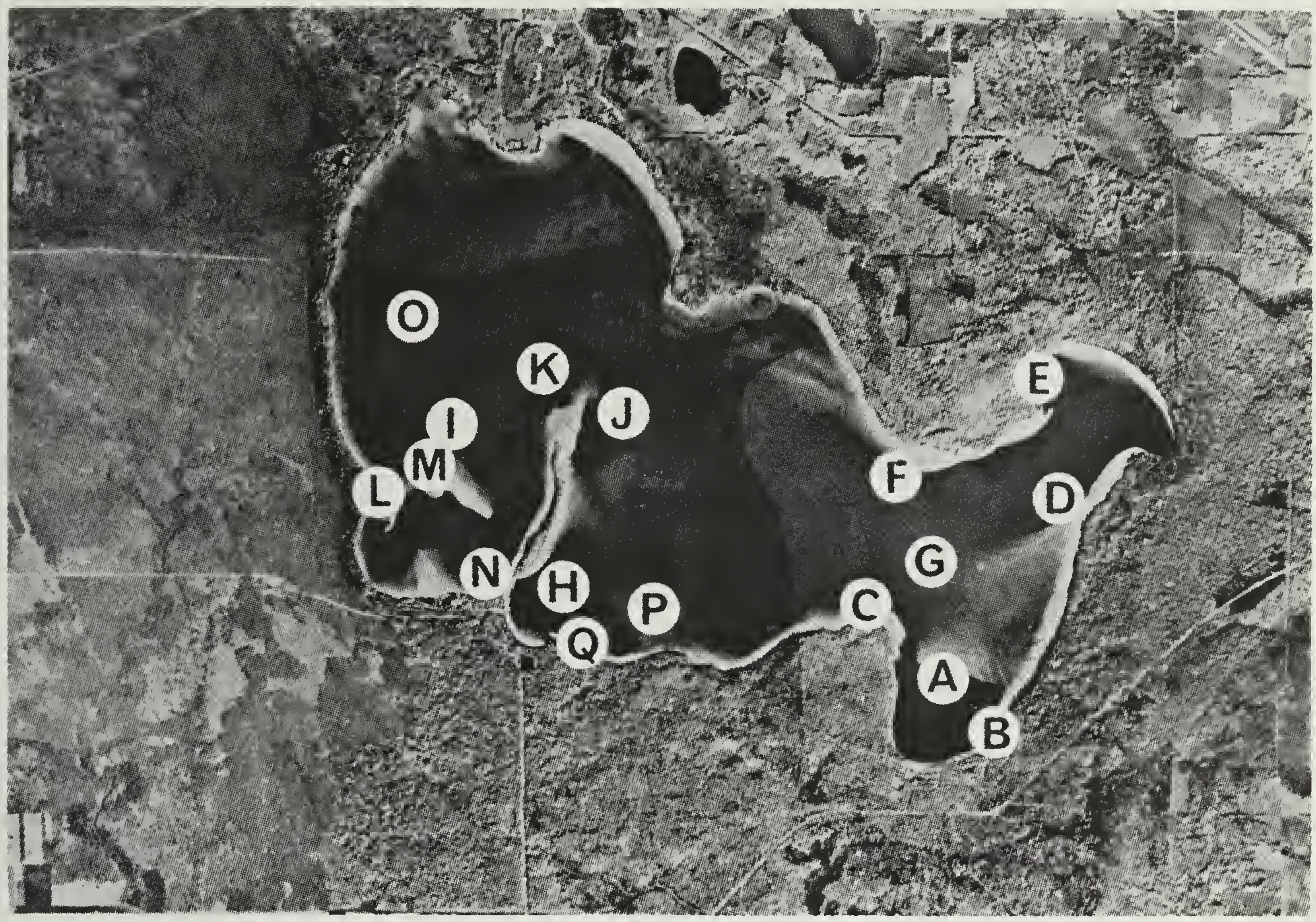

Fig. 2. Douglas Lake with drop offs indicated by letter (photograph of an original by G. R. Williams).

the entire shore, either on foot or very near shore by boat. The following are the exceptions to the above statements: Site 7 is a lake site only and covers the area from approximately the two meter contour out to around four meters. Therefore, site 6 goes from shore out to the two-meter contour. Site 10 is the Sedge Point beach pools. Site 17 is the north-northwest drop-off of Big Shoal and 19 is the south drop-off. Thus, the shore is covered by sites 16, 18, 20. Site 21 is the UMBS boatwell only. Locality 30 follows the east drop-off north of Fairy Island. Site 31 follows the drop-off west of the island from near the southern tip of the island north to the point marked K on Fig. 2. This site also covers the west shore of the island. Site 37 follows the drop-off marked M (Fig. 2) and sites 38 and 39 follow the drop-off marked I (Fig. 2).

Specimens were collected by wading in the shallow areas and with a grappling hook in deeper areas. At each locality the species present and the growth conditions of the plants were noted, e.g., whether stranded, emergent, or submersed (with depth of water). No attempt was made to quantify the samples. The collection period was the summers of 1975 and 1977. Voucher specimens were not prepared so long as a specimen of the species is on file from Douglas Lake in the UMBS herbarium.

We recognize six main species associations—four among the submersed, floating-leaved, and emergent species and two among those of the shore line: (1) In the bays with organic and/or marl substrates, the most evident species are *Nuphar variegatum, Nymphaea odorata, Potamogeton natans, P. friesii, Najas flexilis, Megaladonta beckii, Utricularia cornuta, U. resupinata, U. vulgaris, Polygonum amphibium, Equisetum fluviatile, Sagittaria latifolia, Eleocharis smallii,* and *Carex rostrata.* (2) Along the drop-offs, *Potamogeton natans, P. illinoensis, P. pectinatus, P. zosteriformis, P. gramineus, P. friesii, P.*

praelongus, P. richardsonii, Najas flexilis, N. guadalupensis, Elodea canadensis, Vallisneria americana, Ceratophyllum demersum, Utricularia vulgaris, and *Myriophyllum exalbescens* are the most common species. (3) *Potamogeton praelongus* is the only species consistently found in open water of four to five meters depth other than along a drop-off. (4) Sandy flats in which the water is one-half meter or less deep usually are inhabited by only two submerged species, *Potamogeton filiformis* and *P. gramineus,* and four species of emergents, *Eleocharis smallii, Equisetum fluviatile, Scirpus acutus,* and *S. americanus.* (5) The sandy shores are almost always inhabited by *Lycopus americanus, Mentha arvensis, Spartina pectinata,* and *Solidago graminifolia.* (6) Along the shores with organic substrates, *Myrica gale, Alnus rugosa, Iris versicolor, Typha latifolia, Asclepias incarnata, Lobelia cardinalis, L. kalmii, Eupatorium maculatum, E. perfoliatum, Osmunda regalis, Onoclea sensibilis,* and *Thelypteris palustris* are the most evident species.

According to Gannon & Brubaker (1969), the predominating winds on Douglas Lake are from the west, southwest, and northwest. As a result, the main current flow is from west to east. Once the currents reach Big Shoal, they diverge at Pine Point. Water north of Pine Point flows toward North Fishtail Bay and water south of it moves into South Fishtail Bay. In South Fishtail Bay a clockwise eddy is formed by both the surface and subsurface waters (Gannon & Fee, 1970) sweeping south and then west along the drop-off until it reaches the UMBS boatwell. Thus substrate material is constantly being moved along the southern drop-off of South Fishtail Bay. In North Fishtail Bay, however, the water entering the bay divides with part of it moving directly into the northeast shore (Tallman, 1975). Very little turns counterclockwise, entering the cove behind Hook Point or striking the shore on the western end of North Fishtail Bay. The rest turns clockwise into the cove behind East Point. Downwelling occurs on the water behind East Point, and it moves back out of the bay along the shoal bank just above the thermocline, cutting sharply the edge of the shoal.

When comparing the data on lake currents complied by the previously mentioned investigators of current with Fig. 2, one notices that certain drop-offs will be heavily wave-swept, others to a lesser degree, and others hardly at all. For example, the drop-off at E, L, and O would receive little, if any, wave action, whereas those at K, C, and D would be heavily wave-swept. Heavy wave action continuously moves soil particles (Tallman, 1975). Therefore, with an unstable substrate, plant communities rarely develop. There are occasional hardy individuals, but in no instance do large populations occur. However, in the protected areas, e.g., E, L, and O, communities become abundant. In other localities, e.g., A, J, and P, luxuriant growth occurs in areas that seem to be heavily wave-swept. These are on the leeward side of the shoal where currents move on or near the surface (because of recently passing over a shallow area) and only slightly below. On the windward side of a shoal, e.g., G and K, current action is deep and very few plants have colonized these drop-offs. A good example illustrating this phenomenon is the small depression between Q and P. Q is on the protected side of the depression and P is on the exposed side. There is a heavy plant growth at Q but very little at P.

Potamogeton epihydrus Raf. has been collected on several occasions washed ashore on the UMBS beach following heavy storms with winds from the north. However, no one has ever found the species rooted in the lake. It does occur in Lancaster Lake, the headwaters of Bessey Creek. Possibly, plants have been washed downstream from that lake. This could explain why the species is washed ashore only during very severe storms from the north—the direction of Lancaster Lake.

In general, we followed Voss (1966) as a guide of which species to include in this survey. With few exceptions, the nomenclature follows Voss (1972) for monocots and Fernald (1950) for pteridophytes and dicots. The numbers following the name of each species represent localities at which we found the species in our surveys. Species for which a voucher is not on file at UMBS are marked with an asterisk.

CHECKLIST OF THE AQUATIC VASCULAR PLANTS OF DOUGLAS LAKE

EQUISETACEAE
- Equisetum fluviatile L.—1, 10, 11, 13, 35—emergent; locally abundant, sandy lake margins or water to ½ m. deep.

ISOETACEAE
- Isoetes echinospora Dur.—13—submersed; rare, water 2 m. deep.

OSMUNDACEAE
- Osmunda regalis L.—2, 13, 15, 35—emergent; rare in organic soils, lake margins.

POLYPODIACEAE
- Onoclea sensibilis L.—2, 10, 13, 35—emergent; rare in organic soils, lake margins.
- Thelypteris palustris Schott—2, 10, 15, 35—emergent; uncommon in organic soils, lake margins.

TYPHACEAE
- Typha latifolia L.—1, 2, 4, 5, 10, 35—emergent; locally common in organic soils, lake margins and water less than 50 cm. deep.

SPARGANIACEAE
- Sparganium americanum Nutt.—1, 2—emergent; rare water to 1 m. deep.
- S. angustifolium Michx.—11, 13—floating; locally abundant, water to 1 m. deep.
- S. chlorocarpum Rydb.—1, 2—emergent; locally abundant, water to 1 m. deep.
- S. minimum (Hartman) Fries—10—submersed or floating; rare in organic soils, water less than ½ m. deep.

POTAMOGETONACEAE
- Potamogeton amplifolius Tuckerm.—1, 11, 16, 18, 19, 20, 22, 26, 34, 37, 40—submersed and floating-leaved; locally abundant, water 1-4 m. deep.
- P. filiformis Pers.—1-6, 8, 9, 11, 13-16, 19, 20, 22, 23, 25-27, 29, 31, 35, 36, 38, 40-43—submersed; very common, sandy soil near shore, water to 1, rarely 2 m. deep.
- P. foliosus Raf.—1, 13, 21—submersed; locally abundant, water 1-2 m. deep.
- P. friesii Rupr.—1, 2, 9, 11, 13, 15, 22, 26, 27, 30, 32, 35-37—submersed; abundant, water ½-2 m. deep.*
- P. gramineus L.—1-4, 6, 8-11, 13-15, 19, 22-24, 26-29, 31, 33-38, 40, 41, 43—submersed and floating-leaved; very widespread and common in the lake, water to 3 m. deep.
- P. illinoenis Morong—3, 5, 12-14, 17-19, 22, 27-29, 31, 32, 36-38, 40, 41—submersed; common, drop-offs, water 2-3 m. deep.
- P. natans L.—1-3, 6, 9-11, 13-15, 18-20, 22, 26-30, 32-41, 43—submersed and floating-leaved; abundant, drop-offs, water 2-3 m. deep.
- P. pectinatus L.—2, 8, 9, 11-15, 18-20, 22, 26, 27, 32, 36-41 submersed; common, water ½-3 m deep.

P. praelongus Wulfen–5, 9, 11, 12, 19, 20, 22, 30, 32, 34-41–submersed; common, water 1-3 m. deep.

P. pusillus L.–1, 2, 19–submersed; rare, water ½-2 m. deep.

P. richardsonii (Benn.) Rydb.–1, 2, 8, 9, 11, 14, 16, 18-20, 22, 26, 27, 29, 32, 33, 35-37–submersed; common, water ½-3 m. deep.

P. robbinsii Oakes–13–submersed; rare, water 1-2 m. deep.

P. strictifolius Ar. Benn.–13, 22, 35, 36–submersed; rare, water ½-2 m. deep.

P. zosteriformis Fern.–1, 5, 11, 13-16, 18-20, 22, 27, 28, 30, 36-41–submersed; abundant, water ½-3 m. deep.

P. gramineus × P. illinoensis–8, 11, 13-15, 19, 20, 22, 25-27, 29, 35, 36, 39–submersed; uncommon, water 1-3 m. deep.*

P. gramineus × P. richardsonii–15, 40, 41–submersed; rare, water ½-3 m. deep.*

P. amplifolius × P. praelongus–5, 20, 22, 29, 30–submersed; rare, water 2-3 m. deep.*

NAJADACEAE

Najas flexilis (Willd.) Rostk. & Schmidt–1-5, 8, 9, 11-16, 18-20, 22-29, 32, 35-38, 40, 41–submersed; abundant, water ½-3 m. deep.

N. guadalupensis (Sprengel) Magnus–26, 32, 36, 40–submersed; rare, water 1-3 m. deep.*

JUNCAGINACEAE

Triglochin palustre L.–15–emergent; rare, lake margin.*

ALISMATACEAE

Alisma plantago-aquatica L.–2–emergent; rare in organic soils, lake margin.

Sagittaria cuneata Sheldon–2–emergent or floating-leaved; locally common, water ½-1 m. deep.

S. latifolia Willd.–1, 2, 4, 10, 13, 15, 35, 36, 41–emergent; common in organic substrate, lake margins and water to ½ m deep.

HYDROCHARITACEAE

Elodea canadensis Michx.–1, 2, 5, 11-13, 18-22, 25-28, 30, 32, 36, 39, 41–submersed; common, water to 3 m. deep.

Vallisneria americana Michx.–2-5, 9, 11-15, 19, 20, 22, 27, 29, 30, 32, 35-41–submersed; locally abundant, water to 3 m. deep.

GRAMINEAE

Calamagrostis canadensis (Michx.) Beauv.–3, 10, 12-16, 22, 24, 25, 35–emergent; locally abundant in sandy soil, lake margin.

Glyceria borealis (Nash) Batch.–2, 10, 13, 16, 41–emergent; locally abundant, lake margin or water to ½ m. deep.

Phalaris arundinacea L.–1-6, 11-13, 15, 20, 25, 31, 32, 35, 36, 40-42–emergent; locally abundant, lake margin.

Phragmites australis (Cav.) Steudel–10, 15, 31, 37–emergent; lake margins or water to ½ m. deep.

Poa palustris L.–2, 10, 27–emergent; uncommon, lake margin.

Spartina pectinata Link–3, 4, 6, 8, 12-15, 20, 22-25, 31, 40–emergent; abundant in sandy soil, lake margin.

CYPERACEAE

Carex comosa Boott–10, 16–emergent; locally common in organic soil, lake margin.

C. lasiocarpa Ehrh.–10, 14, 15–emergent; locally abundant in organic soil, beach pools and lake margin.

C. rostrata Schw.–1, 2, 10, 13–emergent; uncommon in organic soils, lake margin.

C. stricta Lam.–2, 11–emergent; uncommon, lake margin.

C. viridula Michx.–1, 2, 6, 14-16–emergent; uncommon in sandy soil, lake margin.

Cladium mariscoides (Muhl.) Torrey–5, 15, 23-25–emergent; common in marly substrate, lake margin.

Dulichium arundinaceum (L.) Britton–1, 10, 13, 15, 35–emergent; uncommon in organic soil, water ½ m. or less deep.*

Eleocharis acicularis (L.) R. & S.–3, 4, 15, 35–submersed or slightly emergent; uncommon, water to ½ m. deep.

E. elliptica Kunth–3, 5, 11-15, 24–emergent; common in marly substrate, lake margin.
E. smallii Britton–1-3, 10-15, 27, 35, 36, 40, 41–emergent; locally abundant, water to ½ m. deep.
Scirpus acutus Bigelow–1-8, 10-12, 14-18, 23, 24, 26, 35-38, 41-43–emergent; locally abundant, water to 2 m. deep.
S. americanus Pers.–1, 3-6, 10-13, 15, 16, 20, 22-24, 26, 29, 31, 35, 40–emergent; abundant, water to 1 m. deep.
S. cyperinus (L.) Kunth–2, 3, 15–emergent; uncommon, lake margin.
S. subterminalis Torrey–10–submersed or emergent; locally abundant in organic substrate, water to ½ m. deep, beach pools.
S. validus Vahl–11, 35–emergent; rare, lake margin.

ARACEAE
Acorus calamus L.–2–emergent; rare, water to 2 dm. deep.

PONTEDERIACEAE
Heteranthera dubia (Jacq.) MacM.–1, 2, 12-15, 19, 20, 22, 26, 27, 32, 34, 35, 37, 39, 40–submersed; locally common, water ½-3 m. deep.

JUNCACEAE
Juncus alpinus Vill.–1, 15, 41–emergent; uncommon, lake margin.
J. balticus Willd.–15–emergent; rare in sandy soil, lake margin.
J. dudleyi Wieg.–2, 3–emergent; rare, lake margin.
J. effusus L.–23–emergent; rare, lake margin.
J. nodosus L.–1, 14, 15–emergent; uncommon in sandy soil, lake margin.

IRIDACEAE
Iris versicolor L.–2, 10, 15, 35–emergent; common in organic soil, lake margin.*

SALICACEAE
Salix interior Rowlee–11, 15, 20, 22, 23–emergent; uncommon in sandy soil, lake margin.
S. lucida Muhl.–11, 15, 20, 22-24–emergent; uncommon, lake margin.

MYRICACEAE
Myrica gale L.–1, 2, 5, 10, 13, 15, 35–emergent; common in organic soil, lake margin.

BETULACEAE
Alnus rugosa (DuRoi) Spreng.–2, 13, 15, 35, 36–emergent; common in organic soil, lake margin.

POLYGONACEAE
Polygonum amphibium L.–2, 3, 10, 12, 13, 15, 18, 23, 24, 35–floating-leaved or emergent; locally abundant, water to ½ m. deep.
P. hydropiperoides Michx.–2, 27, 35–emergent; locally abundant, water to ½ m. deep.
P. persicaria L.–23–emergent; rare, lake margin.

CERATOPHYLLACEAE
Ceratophyllum demersum L.–2, 13, 24, 25–submersed; uncommon, water ½-2 m. deep.

NYMPHAEACEAE
Brasenia schreberi Gmel.–1–floating-leaved; locally common, water ½ m. deep.
Nuphar variegatum Engelm.–1, 2, 10, 13-15, 35, 36–floating-leaved; locally abundant, water ½-2 m. deep.
Nymphaea odorata Ait.–2, 3, 10, 14, 35–floating-leaved; locally common, water 1 m. or less deep.

RANUNCULACEAE
Ranunculus gmelini DC.–2, 41–submersed; rare, water less than ½ m. deep.
R. reptans L.–5–submersed or stranded; locally abundant, water less than ½ m. or lake margin.
R. sceleratus L.–41–emergent; rare, lake margin.*

CRUCIFERAE
Rorippa palustris (L.) Besser–2, 3, 15, 16, 23, 42–emergent; uncommon, lake margin.

ROSACEAE

Potentilla palustris (L.) Scop.—10, 13, 15—emergent locally common in organic soil, water to ½ m. deep.*

LEGUMINOSAE

Lathyrus palustris L.—10, 16—emergent; uncommon, lake margin.

AQUIFOLIACEAE

Ilex verticillata (L.) Gray—2, 10, 35—emergent; common, lake margin.

GUTTIFERAE

Hypericum boreale (Britt.) Brickn.—1, 10—emergent; locally abundant, beach pools and lake margin.*

H. canadense L.—3, 15—emergent; uncommon, lake margin.

H. virginicum L.—5, 10, 15, 35—emergent; common in organic soil, lake margin.*

LYTHRACEAE

Decodon verticillatus (L.) Ell.—3, 13—emergent; locally abundant in mucky soil, lake margin.

ONAGRACEAE

Ludwigia palustris (L.) Ell.—2—emergent; locally common at stream edge.

HALORAGIDACEAE

Myriophyllum exalbescens Fern.—1, 3, 4, 7-9, 11-16, 18-28, 30-35, 37-41—submersed; abundant in water 1-2 ft deep. Probably the most abundant species in the lake, especially in late summer.

Proserpinaca palustris L.—10, 15—emergent; locally abundant, water to ½ m. deep, in beach pools.*

UMBELLIFERAE

Sium suave Walt.—2, 35—emergent; rare in organic soil, lake margin.

CORNACEAE

Cornus stolonifera Michx.—2, 10, 13, 35—emergent; uncommon, lake margin.

PRIMULACEAE

Lysimachia terrestris (L.) BSP—11, 16, 23-25—emergent; common, lake margin.

L. thyrsiflora L.—2, 10, 13, 15—emergent; uncommon, lake margin.

ASCLEPIADACEAE

Asclepias incarnata L.—2, 10, 16, 23, 35—emergent; uncommon, lake margin.

LABIATAE

Lycopus americanus Muhl.—1, 3, 12, 13, 15, 16, 20, 22-24, 35—emergent; common, lake margin.

L. uniflorus Michx.—12, 35—emergent; uncommon, lake margin.*

Mentha arvensis L.—1-3, 12, 15, 16, 20, 22-25, 27—emergent; common, lake margin.

M. piperita L.—1, 20—emergent; rare in sandy soil, lake margin.

Scutellaria epilobifolia A. Hamilton—2, 15, 23, 35—emergent; common, lake margin.

S. lateriflora L.—3, 23—emergent; uncommon, lake margin.

SOLANACEAE

Solanum dulcamara L.—2, 41—emergent; uncommon, stream margin.*

SCROPHULARIACEAE

Mimulus ringens L.—1, 2—emergent; rare, water less than ½ m. deep.

Veronica americana (Raf.) Schw.—41—emergent; rare in sand, lake margin.*

V. scutellata L.—1, 2—emergent; rare, lake and stream margin.

LENTIBULARIACEAE

Utricularia cornuta Michx.—5, 12, 13, 15, 23—submersed or emergent; flowering material rare in marly substrate, water to 1 m. deep. This species and U. resupinata are difficult to distinguish in vegetative condition. Therefore, although vegetative plants were abundant in many localities, the only stations indicated for these species are ones in which flowering plants were observed.

U. intermedia Hayne—2, 13, 16—submersed; uncommon, water less than ½ m. deep.

U. minor L.—9, 40—submersed; rare, water 1-3 m. deep.

U. resupinata B. D. Greene—1, 2, 12—submersed or emergent; flowering material rare, water less than ½ m. deep.

CAMPANULACEAE

Campanula aparanoides Pursh—5, 12, 13, 15—emergent; uncommon, lake margin.

Lobelia cardinalis L.—2, 4, 5, 12, 13, 23—emergent; uncommon, lake margin.

L. kalmii L.—5, 12-15—emergent; locally common in marly soil, lake margin.

COMPOSITAE

Bidens frondosa L.—12, 20—emergent; rare, lake margin.

Eupatorium maculatum L.—3, 4, 15, 22, 24, 31, 36—emergent; uncommon, lake margin.

E. perfoliatum L.—3, 4, 12, 13, 15, 22—emergent; uncommon, lake margin.

Megalodonta beckii (Torr.) Greene—13, 26, 32, 34-37—submersed; locally abundant, water 1-3 m. deep.*

Solidago graminifolia (L.) Salisb.—5, 8, 12, 13, 15, 16, 20, 22-25, 31—emergent; locally abundant in sandy soil, lake margin.

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The March issue (Vol. 17, No. 2) and the May issue (Vol. 17, No. 3) were mailed May 26, 1978.

CONTENTS

Vascular Flora of the Ravines along Lake Michigan in Lake County, Illinois
Robbin C. Moran 123

Morphological Variation of Families of Trembling Aspen in Southeastern Michigan
Michele M. Farmer & Burton V. Barnes 141

Publications of Interest 154

Lichens of the Mackinac Straits Region. II. Candelariella Müll. Arg.
Richard C. Harris & William R. Buck 155

Ptychomitrium, a Moss Genus New to Michigan
William R. Buck 162

Michigan Plants in Print 163

Pollen Abortion in Betula and Populus (Section Leuce)
Burton V. Barnes 167

Comparison of Roots and Stems of Alfalfa Seedlings Grown on Soil and Copper Tailings
Patricia A. Dean and Frederic H. Erbisch 173

Nathan Wright Folwell, Asa Gray's Botanical Correspondent in Michigan
Ronald L. Stuckey 177

The Distribution of the Aquatic Vascular Flora of Douglas Lake, Cheboygan County, Michigan
Robert R. Haynes & C. Barre Hellquist 183

On the cover: The Straits of Mackinac,
taken from NASA Landsat satellite, June 2, 1976,
at an altitude exceeding 500 miles (Ident. no. E-2497-15400)

93
18

Vol. 18, No. 1

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THE CLUBMOSSES LYCOPODIUM SITCHENSE AND L. SABINIFOLIUM IN THE UPPER GREAT LAKES REGION

Joseph M. Beitel

Department of Botany
University of Michigan,
Ann Arbor, 48109

The clubmosses of North America have been the subject of much study, but problems still exist in identification and interpretation. There are numerous problems of subtle species characters, hybridization, and sun vs. shade forms. This paper deals with two rare northern taxa about which there have been a number of questions.

The characters that distinguish the Sitka clubmoss, *Lycopodium sitchense,* and the savin-leaved clubmoss, *L. sabinifolium,* have been the subject of controversy from the time of their descriptions. The type sheet from which *L. sabinifolium* was described by Willdenow in 1810 contains two specimens (Lloyd & Underwood, 1900), one possessing the decussate, four-ranked leaves corresponding to the type description of *L. sabinifolium (foliis lanceolatis acutis quadrifariis).* The other specimen with spirally arranged, five-ranked leaves belongs to *L. sitchense* Ruprecht, which was not described until 1845. Fernald (1923), in reducing *L. sitchense* to a variety of *L. sabinifolium,* stated that the extreme forms of the two taxa are distinctive but that they are a result of environmental conditions. Thus, most specimens of *L. sitchense,* a plant of open and alpine habitats, have the typical sessile strobili and five-ranked leaves. *Lycopodium sabinifolium,* a plant found in woodland and thickets, possesses strobili with longer peduncles and four-ranked leaves—characters (according to Fernald) induced by the environment.

The intermediate nature of *Lycopodium sabinifolium* between *L. sitchense* and the ground cedar, *L. tristachyum,* was noticed by Victorin (1925) and Wilce (1965). Victorin's suggestion that this represents a linear series of evolution from *L. sitchense* to *L. tristachyum* was rejected by Wilce in her monograph of the section Complanata. She concluded from a study of morphological and anatomical characters that *L. sabinifolium* represents, instead, a hybrid between *L. sitchense* and *L. tristachyum.* In comparing 17 characters of each species, she found that *L. sabinifolium* showed two *sitchense* characters, two *tristachyum* characters, ten intermediate characters, and three characters unlike those of either of the presumed parents. A summary of these characters appears in Table 1. One of the most distinctive features deals with the base of the strobilus (fig. 1). Both *L. sitchense* and *L. tristachyum* have well-defined strobilar bases with compact sporophylls. In *L. tristachyum* the strobili are borne on long, usually twice-forking peduncles, while in *L. sitchense* the strobili are either sessile on the fertile branch or borne singly on an extremely short peduncle. An intermediate peduncle length is observed in *L. sabinifolium,* but instead of the strobilus having a sharply

TABLE 1. Summary of character-differences between *Lycopodium sitchense, L. sabinifolium,* and *L. tristachyum* (modified from Wilce, 1965)

	sitchense	*sabinifolium*	*tristachyum*
Range	Boreal to subarctic, No. Amer. and Japan	North temperate to boreal, eastern No. Amer.	North temperate to boreal, eastern No. Amer. and Europe
Nature of rhizome	Superficial	Superficial to subterranean	Subterranean
Aerial sterile shoots	Round-branched, isophyllous	Dorsiventrally flattened, nearly isophyllous; upper and lower surfaces convex	Flat-branched, heterophyllous; lower surface concave
Ranks of leaves	5	4	4
Color of leaves and branches	Green (rarely bluish-green), shiny	Green to bluish-green ± glaucous	Bluish-green, glaucous
Stomate location on leaves	Both surfaces	Both surfaces	Lower surfaces only
Nature of fertile shoot	Strobili 1, sessile on fertile branch or short peduncle	Strobili 1(-2), on short to long, unforked (or rarely forked) peduncle	Strobili 3-4, on long (8 cm.), 2-forked peduncle
Strobilus base	Compact, sharply distinct from leafy fertile branch	Basal sporophylls scattered along peduncle	Compact, sharply distinct from peduncle
Sporophyll shape	With long, gradually tapered apex	With more rapidly tapered apex	With short, abruptly tapered apex

defined base, sporophylls and sporangia are scattered at greater and greater distances down the peduncle. This peculiar scattering of the strobilus down the peduncle is observed in other hybrids (such as *L.* X*issleri,* a hybrid between the sessile-coned *L. alpinum* and the pedunculate *L. complanatum*).

Another distinctive feature which Wilce enumerated is the flattened arrangement of the four-ranked leaves in *Lycopodium sabinifolium* (fig. 2). The sterile branches are somewhat dorsiventrally flattened with convex, nearly identical upper and lower surfaces, in contrast to the normal situation in other taxa of the section Complanata which have dorsiventrally flattened branches, as in *L. tristachyum.* In these taxa, the lower surface is concave and different in leaf morphology from the upper surface. A hybrid between this heterophyllous, flat-branched type and an isophyllous, five-ranked, round-branched taxon (such as *L. sitchense*) would be expected to have the four-ranked, dorsiventrally flattened branches similar on both surfaces found in *L. sabinifolium.* It should be mentioned as a word of caution that all three taxa have

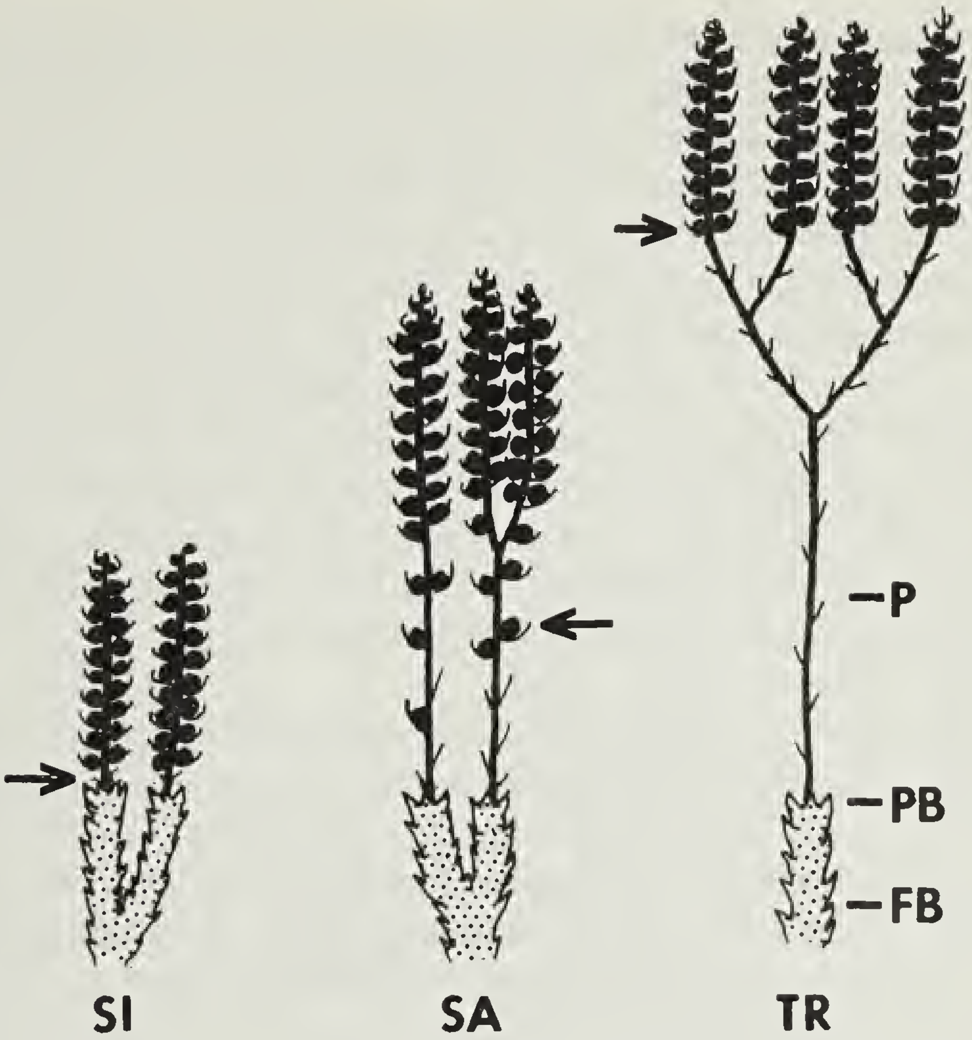

Fig. 1. Diagram of reproductive shoots. P = peduncle; PB = peduncle base; FB = fertile branch. SI: *Lycopodium sitchense,* arrow = sharply defined strobilus base, short or non-existent peduncle. SA: *L. sabinifolium,* arrow = scattered sporangia and sporophylls. TR: *L. tristachyum,* arrow = sharply defined strobilus base; long, twice-forked peduncle.

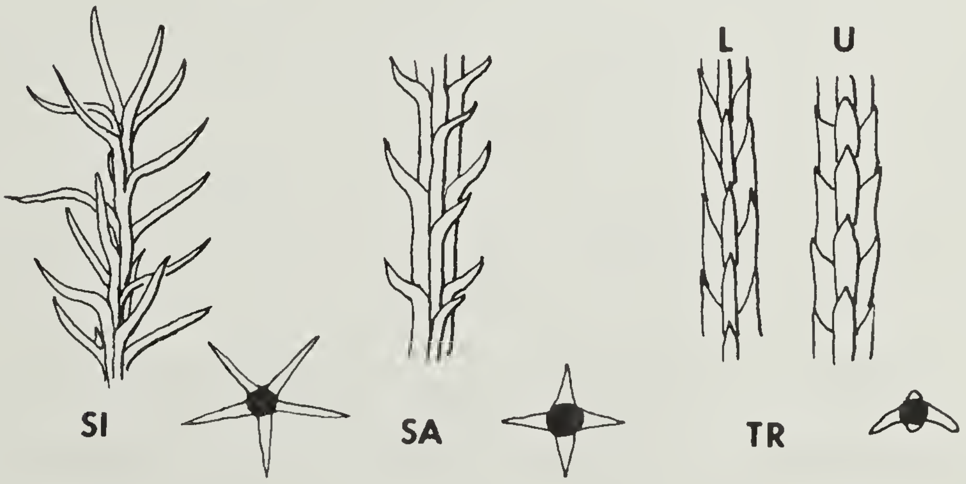

Fig. 2. Diagram of sterile branches (surface and cross-section). SI: *Lycopodium sitchense.* SA: *L. sabinifolium;* upper & lower surfaces similar. TR: *L. tristachyum;* L = lower surface, U = upper surface.

round fertile branches with spirally arranged leaves. These branches, which bear the strobili and their peduncles, should not be confused with the sterile branches, to which the previous characters pertain.

The ranges of the three species fit the hypothesis of a hybrid origin for *Lycopodium sabinifolium. Lycopodium sitchense* is a boreal to subarctic species found in North America and Asia, east to Greenland and west to Japan. *Lycopodium tristachyum* is a north temperate to boreal species occurring in eastern North America west to Minnesota and in Europe east to Turkey and the Urals. *Lycopodium sabinifolium* occurs in the area of overlap between the two presumed parental ranges, that is, in eastern North America from Thunder Bay, Ontario, and northern Michigan east to Labrador and south to Maryland. Its distribution seems to be centered in the Laurentian region of Quebec, where glacial disturbance may have played a part in the process of hybridization (Wilce, 1965).

The chromosome number of both *Lycopodium sitchense* and *L. tristachyum* is 2n = 46 (Wilce, 1965). The number for *L. sabinifolium* of 2n = 46 (Löve, 1976) is consistent with reports of other hybrids in the section Complanata. Hybrids in this section appear to be diploids, even though morphologically they are intermediate between other diploid species, for example, *L.* X*issleri* (= *L. alpinum* X *complanatum*) and *L. complanatum* X *tristachyum* (Damboldt, 1963).

The status of *L. sitchense* and *L. sabinifolium* in Michigan has been the subject of confusion for many years. Billington (1952), in his *Ferns of Michigan,* gave two localities for *L. sabinifolium* in the western Upper Peninsula (Iron and Marquette Counties). Through the use of notes made by the late Dale Hagenah, it has been possible to identify the two specimens on which the reports were based. The two specimens, Grassl 7214 and Gillman, July 25, 1867, were listed by Wilce (1965) as *L. tristachyum;* she discounted Billington's two *L. sabinifolium* records without indicating what specimens they were based on. The single confirmed locality for either of the taxa in question was reported from Chippewa County in the Upper Peninsula by Hiltunen (1961), who reported a number of unusual northern pteridophytes concentrated in a flat, open area among low, broad, sandy ridges of swampland dominated by black spruce *(Picea mariana).* This area, actually a shallow excavation (or a borrow pit) southwest of Hulbert, resulted from the removal of sandy ridges for the building of Rte. 28 in 1935. The moist open surface of acidic sand provided a habitat for the propagation of *Lycopodium* species which establish themselves in early stages of succession. Hiltunen reported the occurrence of common clubmoss *(L. clavatum),* bog clubmoss *(L. inundatum)*, and ground cedar *(L. tristachyum),* as well as the rarer, northern fir clubmoss *(L. selago),* and what he called the Sitka clubmoss *(L. sitchense).* The last taxon, collected in 1957, was represented by a rhizome with four or five aerial shoots, all sterile. The identification was confirmed for Hiltunen by Wilce and reported in her monograph as the single known record of *L. sitchense* for Michigan. Even though she did her work on the section Complanata at the University of Michigan, she reported that she had never seen *L. sitchense* in the field in Michigan.

Based on these reports, *Lycopodium sitchense* was included in the list of rare and endangered species for Michigan (Wagner *et al.*, 1977) as an endangered species. Plants designated as "*L. sitchense*" from the Hulbert borrow pit appeared on the cover of the October 1977 issue of *The Michigan Botanist.*

The Hulbert borrow pit has continued to provide an ideal habitat for the development of Lycopodiums; additional colonies established there include bristly clubmoss *(L. annotinum)*, round-branched tree clubmoss *(L. dendroideum)*, flat-branched tree clubmoss *(L. obscurum)*, running pine *(L. flabelliforme)*, and northern running pine *(L. complanatum)*, as well as the hybrids *L. flabelliforme* X *tristachyum* *(L.* X*habereri)* and *L. selago* X *lucidulum.* The excavation has for the most part remained open, although scattered and stunted black spruces have appeared throughout the open area, now 43 years old.

The colony of plants identified as *L. sitchense* has now (1977) expanded in the open area to eight to ten feet in diameter and produces many fertile branches. It has also extended into the shade of some small (2 ft.) black spruces about six feet from the center of the colony. On the basis of the fertile branches and the behavior of the plant in the shade, after its initial identification as *L. sitchense* 17 years ago, the Hulbert borrow pit plant has showed itself actually to be *L. sabinifolium.* The basis for this significant change in interpretation is discussed below.

Specimens of *L. sitchense* and *L. sabinifolium* from the following herbaria were examined: US, GH, NY, MICH, MSC, BLH, MCT, NM, CMC, WMU and WUD. The specimens from Michigan, all from the Hulbert borrow pit and all *L. sabinifolium,* were Hiltunen 917 (WUD) & 4397 (MICH, WUD), Hagenah 7118 (BLH), Voss 13450 (MICH, MSC) & 14171 (NY, GH). Hiltunen 917 (not stored at MICH as reported by Wilce, 1965) is the original specimen collected by Hiltunen in 1957 and identified as "*L. sabinaefolium* var. *sitchense*" by Wilce in 1958. It consists of two sterile upright branches of the sun form of *L. sabinifolium.* In addition, the fragments of the two specimens on the type sheet of *L. sabinifolium* sent by Pritzel from Berlin (Lloyd & Underwood, 1900) were examined at NY, as well as the microfiche (MICH) of the Willdenow specimen. It is clearly evident that one specimen conforms to the type description of *L. sabinifolium* on the basis of branch morphology, while the other specimen is *L. sitchense.* The two specimens reported as *L. sabinifolium* by Billington and later annotated by Wilce as *L. tristachyum,* Grassl 7214 (MICH) and Gillman, July 25, 1867 (NY), were examined and found to be correctly annotated as sun forms of *L. tristachyum.*

Two of the biggest problems in *Lycopodium* systematics are hybridization and the modifying effects of the environment. They more often than not combine to make the subtle differences between the basic species even harder to make out, as is the case here. A plant growing in the sun will often look radically different from a shade-grown specimen of the same taxon or even the same clone. Even the reproductive structures may change (Wagner & Beitel, 1979). Only through extensive observation of the taxa in the field under various conditions can the true range of variation of individual taxa be appreciated. Fernald (1923) was on the right track about the importance of environmental effects, except that he did not pursue the question on the basis of two taxa each responding separately to the environment, but rather as environmental extremes of one species. The Hulbert borrow pit provides an excellent opportunity to examine the behavior of *L. sabinifolium* in both sun and shade.

The specimens from the borrow pit in the sun have a compact growth habit and strobili about two centimeters in length, the whole plant being about eight centimeters tall (fig. 3A). They do have the general appearance and coloration of *Lycopodium sitchense* except that the strobili are borne on short peduncles (fig. 6C). Wilce (1965) pointed out that this often occurs in *L. sitchense* from the eastern part of its range and attributed it to introgression of genes from *L. sabinifolium.* However, the basal portions of the strobili are ill-defined with the sporophylls scattered down the peduncles. The leaves are borne extremely close together owing to a growth reaction to direct sun, and their four-ranked nature is exceedingly difficult to see (fig. 7A). The fact that the upper and lower surfaces are essentially identical adds difficulty. The shade-grown individuals of this clone reveal their identity much more clearly. They are markedly larger (15 cm.) and much more spreading (fig. 3C). The peduncles vary in length, with some being almost eight centimeters long, including their strobili (fig. 6A). The characteristic "straggling" sporophylls

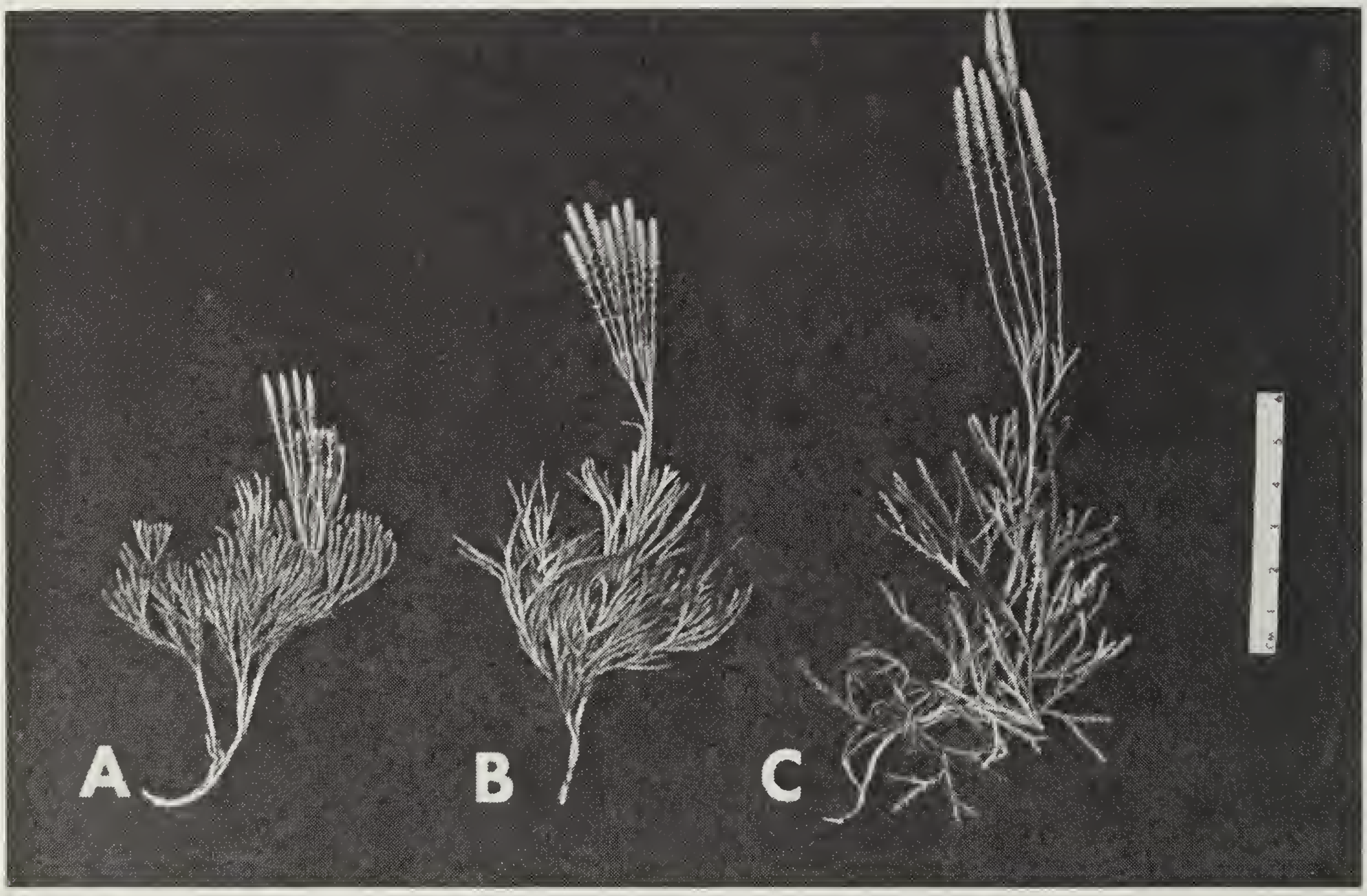

Fig. 3. *Lycopodium sabinifolium;* single clone, Hulbert borrow pit, Chippewa Co., Mich ×1/3. A. Sun form (Beitel 77270). B. Intermediate form (Beitel 77339). C. Shade form (Beitel 77339).

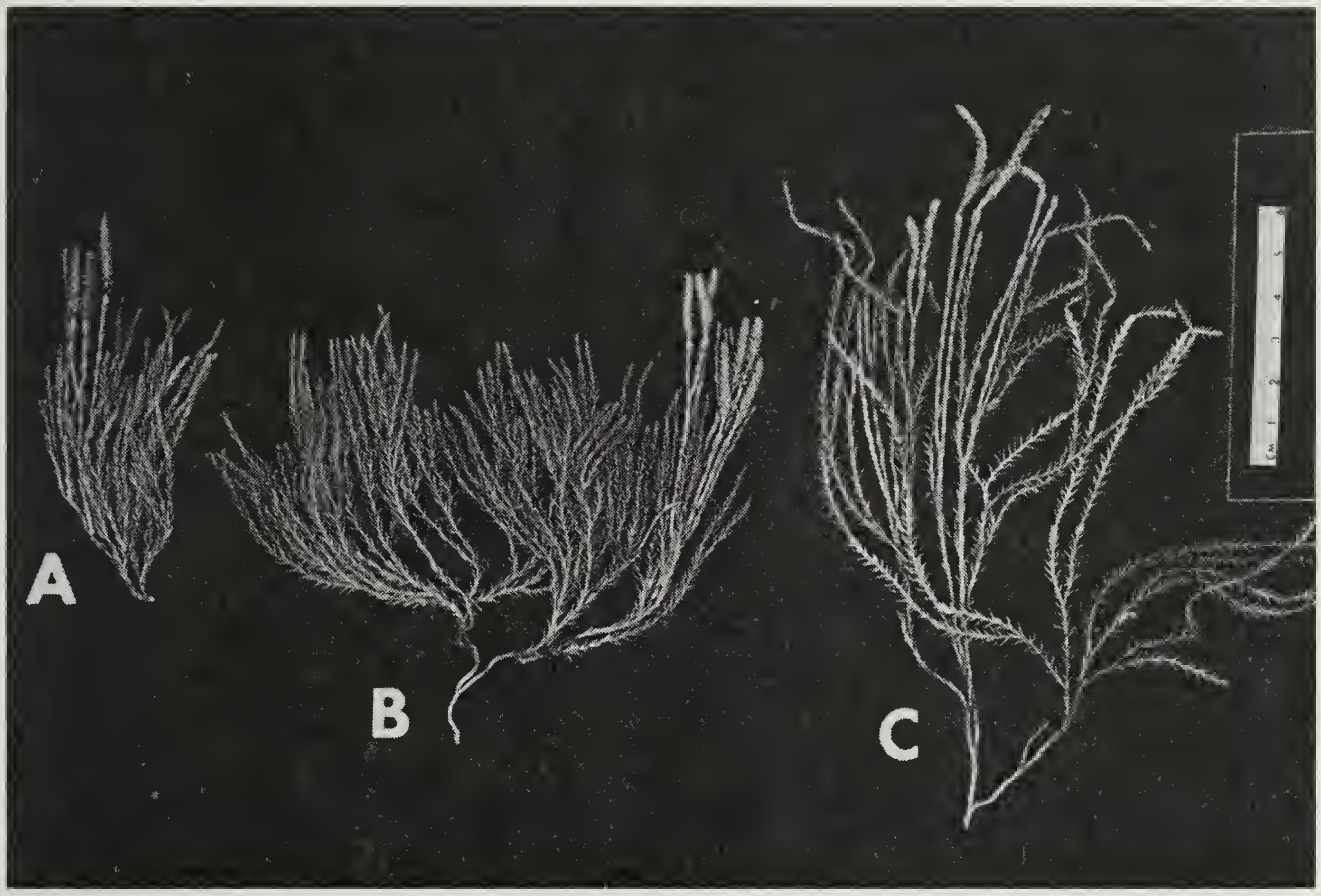

Fig. 4. *Lycopodium sitchense;* White River, Algoma District, Ontario (Voss 14961). ×1/3. A. Sun form. B. Intermediate form. C. Shade form.

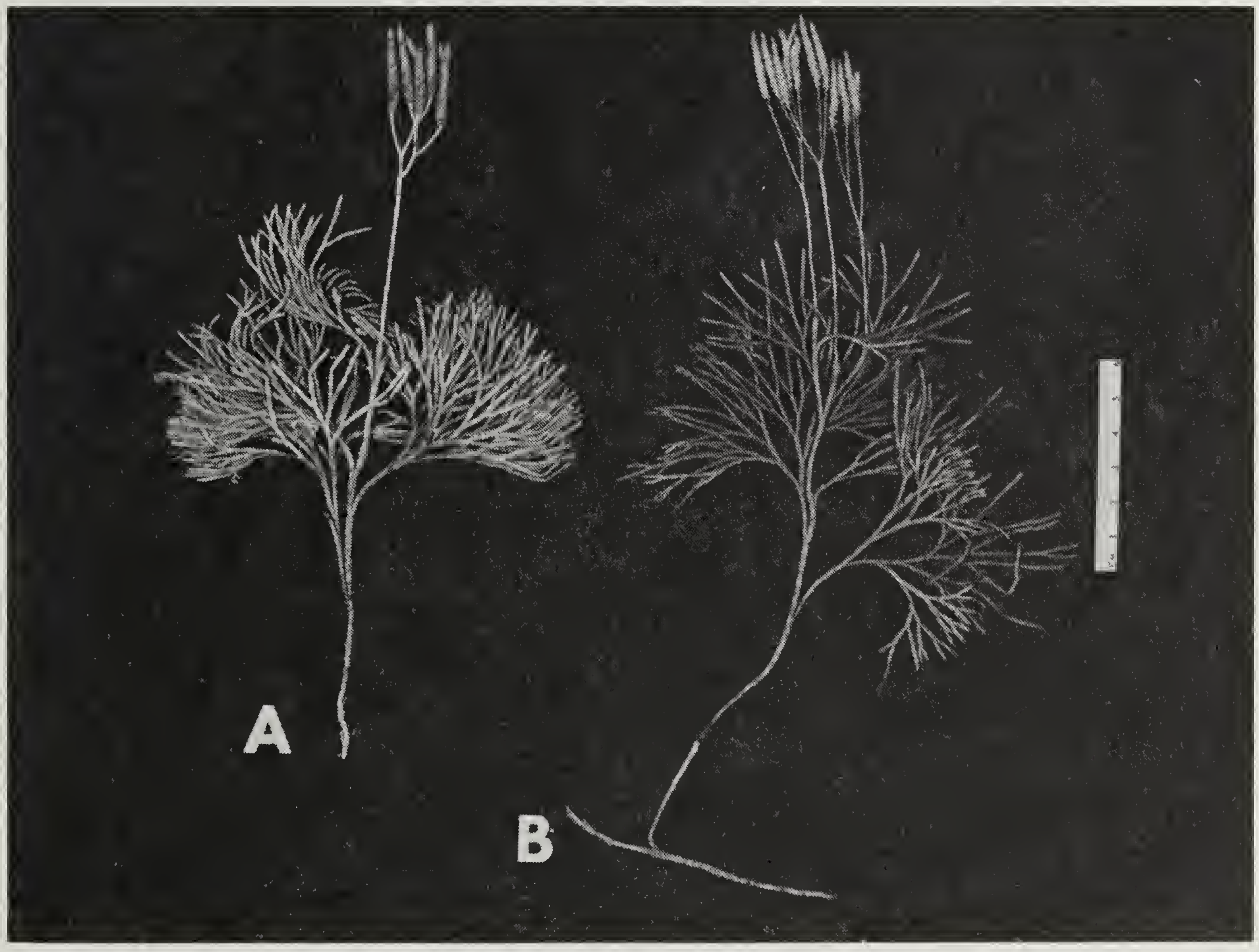

Fig. 5. *Lycopodium tristachyum;* ×1/3. A. Sun form (Beitel 74207, Hulbert borrow pit, Chippewa Co., Mich.). B. Shade form (Beitel 98, Yaphank, Suffolk Co., N.Y.).

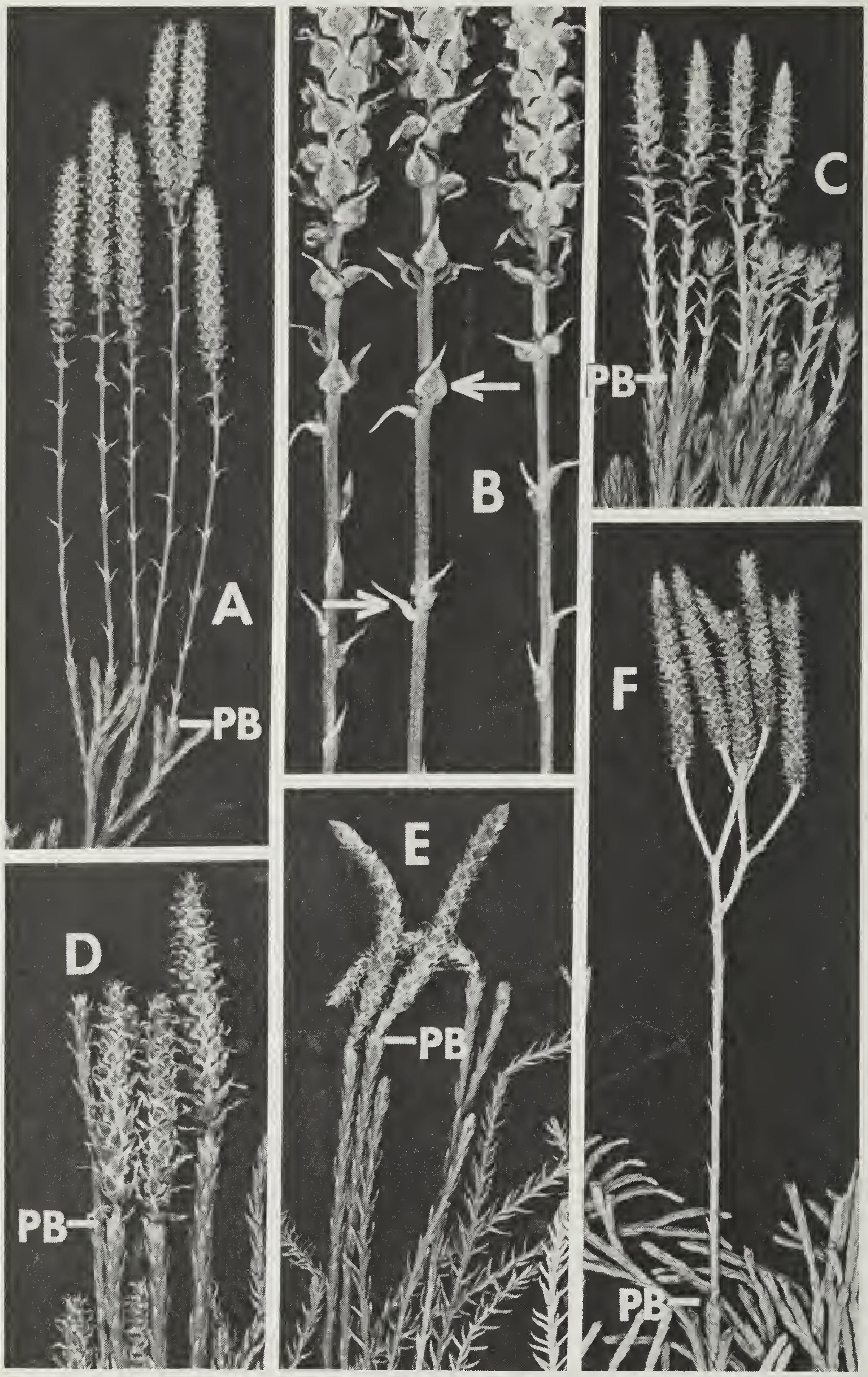

Fig. 6. Reproductive shoots. PB = peduncle base. A. *Lycopodium sabinifolium* (Beitel 77339), shade form. ×1.1. B. *L. sabinifolium* (Beitel 77339), arrow = scattered sporangia. ×3.7. C. *L. sabinifolium* (Beitel 77270), sun form. ×1.8. D. *L. sitchense* (Voss 14961), sun form. ×1.8. E. *L. sitchense* (Voss 14961), shade form. ×1.8. F. *L. tristachyum* (Beitel 74207), sun form. ×1.0.

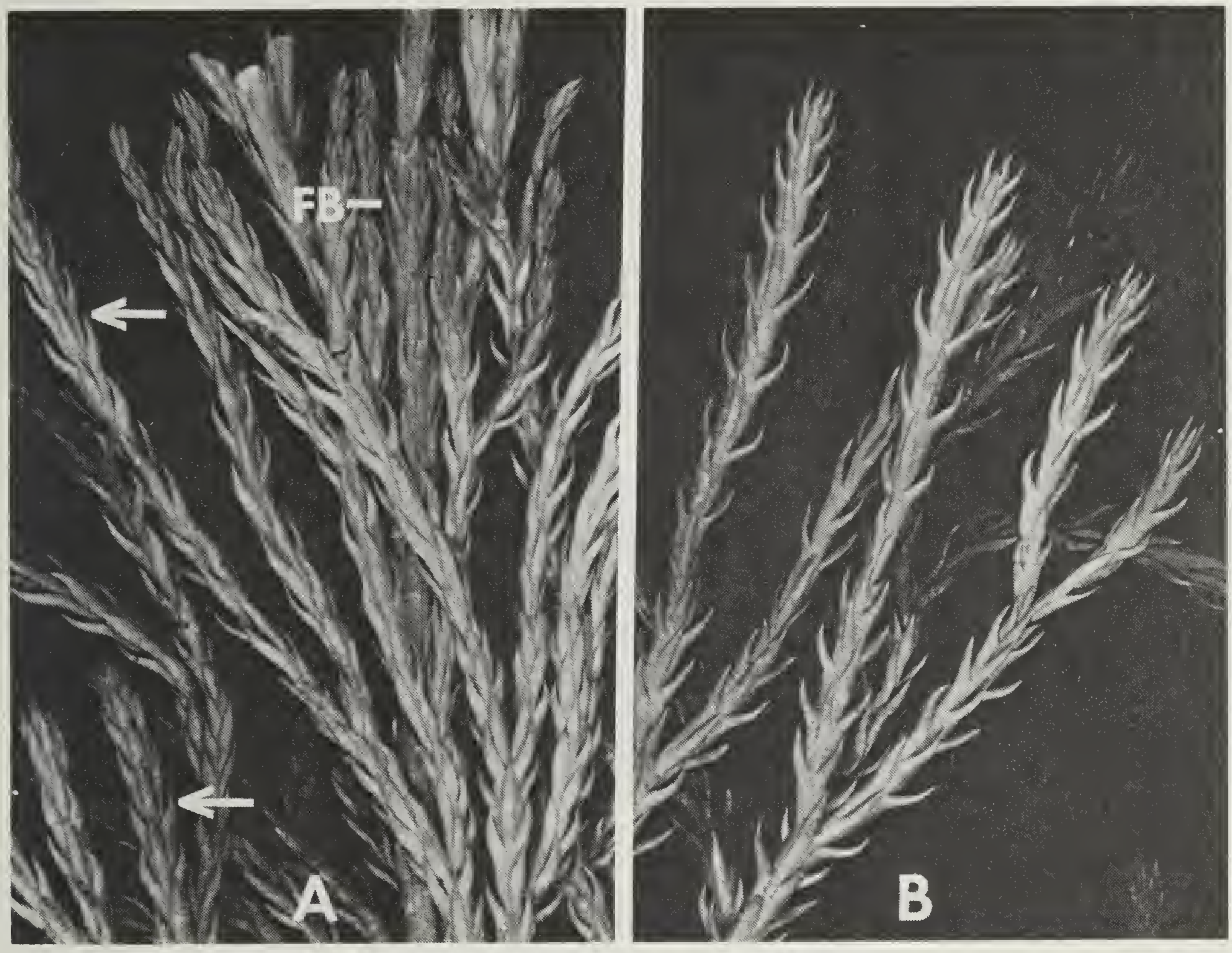

Fig. 7. *Lycopodium sabinifolium,* sterile branch system. ×2.4. A. Sun form (Beitel 77270), FB = fertile branch, arrow = 4-ranked leaves. B. Shade form (Beitel 77339).

under the strobilus bases are well developed (fig. 6B), and the peduncles occasionally even fork. The branches are clearly flattened dorsiventrally with similar top and bottom surfaces and four-ranked leaves (fig. 7B). The shade forms resemble *L. tristachyum* much more than *L. sitchense* and might be confused with it in a woodland situation, except for the peculiar sporophylls and the nature of the leaves.

An opportunity for me to study the apparent responses of *Lycopodium sitchense* to both sun and shade environments was provided by Dr. Edward G. Voss and his Boreal Flora class at the University of Michigan Biological Station during the summer of 1977. The class made a mass collection of *L. sitchense,* unsorted, but derived from both sunny and shady sites, in an open black spruce-jack pine forest ten miles southeast of the town of White River, Algoma District, Ontario, during a trip to the north shore of Lake Superior. Some of the specimens from the site with compact growth form (fig. 4A), sessile strobili on long fertile branches (fig. 6D, FB), and spiral, five-ranked leaves of typical *L. sitchense* (fig. 8A) correspond to the sun form of *L. sitchense.* The laxer and larger forms (fig. 4C) retain the essential features of the strobili and sterile branches, but the greater height of the plant results from a longer leafy fertile branch rather than an intercalation of a naked peduncle, of which there is no trace (fig. 6E). The leaves of this form (which

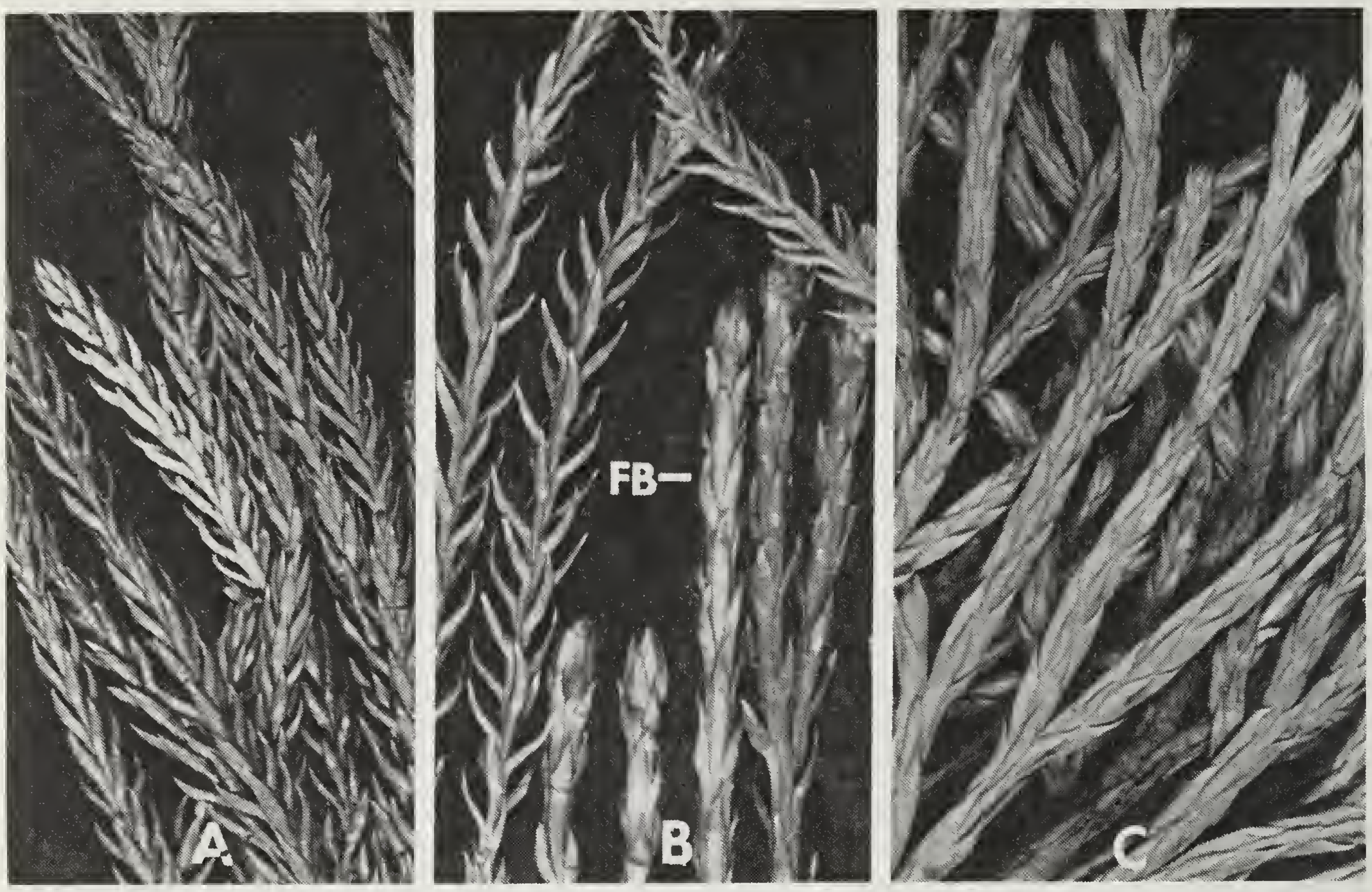

Fig. 8. Sterile branch system. ×2.4. A. *Lycopodium sitchense* (Voss 14961), sun form. B. *L. sitchense* (Voss 14961), shade form, FB = fertile branch. C. *L. tristachyum* (Beitel 74207), sun form.

corresponds to the shade form) are larger and more distant but are still spirally arranged in five ranks (fig. 8B).[1]

The sun form of *Lycopodium tristachyum* also has a compact growth habit, with all the sterile branches directed upward (fig. 5A). In the shade, the branches grow more laxly and eventually reflex (fig. 5B). The long, forked peduncle typical of the sun form (fig. 6F) is retained in the shade, along with the heterophyllous nature of the flattened branches (fig. 8C). The specimens of *L. tristachyum* reported as *L. sabinifolium* by Billington were both of the extreme sun form. The Marquette County specimen (Gillman, July 25, 1867) had the long, forked peduncles and heterophyllous branches of *L. tristachyum* but was very compact and possessed ascending branches. The Iron County specimen (Grassl 7214) was sterile, but the heterophyllous branches were evident.

In all three taxa it thus appears that the sun forms are more compact, shorter, and more upright than the shade forms; conversely, the shade forms are laxer, taller, and more spreading. This can be confusing in extreme forms, such as when sun forms of one taxon begin to overlap in general growth habit the shade forms of another taxon. This seemed to be the basic problem in Michigan, where the records of *L. sabinifolium* (Billington, 1952) were actually sun forms of *L. tristachyum,* and the first record of *L. sitchense*

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[1] The White River site was studied by the author on 11 July 1978, and the actual sun and shade forms of *L. sitchense* were found to correspond exactly to the presumed sun and shade forms in the material collected by Dr. Voss and his class in 1977.

(Hiltunen, 1961) was actually a sun form of *L. sabinifolium.* Other intermediate characters result from the hybrid origin of *Lycopodium sabinifolium.* Certain characters (such as the strobilus base and the structure of the sterile branches) are highly reliable and should be examined carefully for identification purposes.

The single presumed locality for *"Lycopodium sitchense"* in the state of Michigan now constitutes instead the sole location for *L. sabinfolium.* This does not mean that *L. sitchense* will not be found as more knowledge is obtained concerning the flora of the Upper Peninsula. The two taxa should be sought in the northern areas of the state, especially in disturbed, acidic, sandy areas. The list of rare and endangered plants for Michigan needs to be emended to replace the name *L. sitchense* by *L. sabinifolium.* Real protection will not be achieved until the habitat of this and the other Lycopodiums at Hulbert has been set aside for management to insure their maintenance, and it may be necessary to block natural succession in order to achieve this goal.

I wish to thank Edward G. Voss, Peter Harley, Robert Ambrose, and the 1977 Boreal Flora class for assistance in this study, as well as the curators of herbaria cited above. Special thanks go to W. H. Wagner, Jr., and Kerry S. Walter for encouragement and critical review of the manuscript, to David Bay for photographs, and to Ethelda Hagenah for access to Dale Hagenah's notes.

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REVIEWS

WILDFLOWERS OF MICHIGAN. Roberta L. Simonds & Henrietta H. Tweedie. 1978. 96 pp. $2.95 [from Mrs. Richard Simonds, 913 Aurora Way, Wheaton, Illinois 60187].

Here is a very attractive, reasonably priced guide with no wasted space or words. Drawings of over 250 wildflowers fill the pages to the margins, and the very brief text concisely adds useful information on flower color, height of plant, habitat, and occasionally striking key characters. There is no statement of distribution within the state, but the Introduction mentions that the drawings were made in "the lake counties of western Michigan" although most species are of wider distribution. A number of very rare (even "threatened") species are included as well as more familiar ones; it is a good representative selection of both native and alien plants, not overemphasizing orchids or other specialties. Nomenclature follows Gleason's *New Illustrated Flora.*

The artist-authors have exhibited their drawings in the Chicago area and southwestern Michigan, so their realistic work will be familiar to some of our readers. The plants were obviously sketched from life, not from pressed specimens. Only a very few would I question either artistically or taxonomically. *"Utricularia cornuta"* does not look right; *Bidens polylepis* and *Liatris ligulistylis* [*"linguistylis"*] do not grow in Michigan, so far as I know, and if the drawings were truly made in this state they probably represent *B. coronatus* and *L. novae-angliae.* The drawings of Beechdrops and Pinedrops are reversed (and Indian Pipe, on the same page, should not have been termed "parasitic"). There are some minor typographical errors and very few other slips (Lupine is not in the Fagaceae, nor are the flowers of *Melilotus alba* yellow). Botanists must tolerantly overlook the very broad application of such terms as seed, spike, stem, and flower.

The basic arrangement is by season (spring, summer, fall), and within each season, by habitat. Similar species which grow together are often displayed on the same page, but not always (e.g. the two Spiraeas). Bog Rosemary blooms in early spring and does not belong under summer. Some other seasonal assignments may also be questioned: Partridge Berry blooms in the summer rather than spring, but Early Coralroot is a spring rather than summer plant; Pokeweed, Flowering Spurge, and Bristly Sarsaparilla are really more summer than fall bloomers.

My quibbles, obviously, are mostly quite trivial. This is an excellent little guide of its kind, with enough different species in it to be really useful to many amateurs, tourists, and visitors to our woods, meadows, bogs, and shores. —E. G. Voss

THE WITCH'S GARDEN. By Harold A. Hanson (transl. from Danish by Muriel Crofts). Unity Press, 113 New St., Santa Cruz, Calif. 95060. Nov. 8, 1978. xii + 128 pp. $4.95 (paper).

By coincidence I am writing this weft of fact and fancy on Halloween. It is a fascinating account of the use made by witches, gypsies, camp followers, and assorted other ne'er do wells and chicken thieves of plant ingredients in medicines, love potions, poisons, and flying ointments. It puts into historical perspective, perhaps, a recent upsurge of interest in pharmaceutical "trips". The information goes back to the beginnings of western civilization and was put together for us by one who has the knowledge and insights of a modern-day botanist. The woodcuts that adorn the book are taken in in square charm from the herbalists. The herbs treated in detail are few—mandrake, henbane, hemlock, deadly nightshade, monkshood, and thornapple. The latter is better known in America as Jimson weed, so named because soldiers stationed in Jamestown, Virginia, in 1676, took it "plentifully" in a soup "the Effect of which was a very pleasant Comedy." In Europe it had long been used as a "tool of brothel-keepers, wicked seducers of girls, depraved courtesans and shameless lechers." Good reading!

—H. Crum

CONIDIAL ULTRASTRUCTURE AND TAXONOMIC AFFINITY OF A FUNGAL PARASITE OF SPHAGNUM

Robert Chau

Department of Botany
University of Michigan
Ann Arbor, 48109

Examining collections of the peat moss, *Sphagnum,* one is likely to find capsules containing small (11-13 μm), alete, "reticulate" spores as well as capsules containing larger (20 μm and more), trilete, granulary-ornamented *Sphagnum* spores. Bauch (1935) has noted that one seldom finds capsules containing both types of spores together, although superficially the capsules look identical. Schimper (1858) and Warnstorf (1886) described these small spores; they have been found in *S. recurvum* and *S. teres* (Bauch, 1935), in *S. centrale* and *S. cuspidatum* (Crum, 1976), and in several other *Sphagnum* species, including the three used in this study. They have been found in the liverworts *Riccia* and *Ricciocarpus* (Ciferri, 1954). They have even been found in Pleistocene peats.

These spores have been considered *Sphagnum* microspores (Schimper, 1858; Warnstorf, 1886), *Tilletia* teleutospores (Nawaschin, 1890), *Bryophytomyces* teleutospores (Ciferri, 1954), and *Helotium* conidia (Bauch, 1935). Dickson reported that some researchers working on fossil peats have even interpreted them as spores of the moss genera *Polytrichum* and *Dicranum.* Such taxonomic confusion results in large part from a lack of understanding of the spore wall ornamentation and ultrastructure. Knowing that these spores arise from fungal hyphae, modern workers are divided nonetheless between considering them smut teleutospores and discomycete conidia[1]. The disagreement arises in part from the inability to distinguish under light microscopy whether or not the spore ornamentation is a reticulum, as is typical of many smut teleutospores. The purpose of this study was to investigate the ultrastructure of the spores, giving special attention to the ornamentation and its taxonomic significance.

Capsules of *S. squarrosum, S. russowii,* and *S. capillifolium* were acetolized in a boiling mixture of 9:1 acetic anhydride: sulfuric acid. After two minutes, the mixture was quenched with acetic acid and then washed in distilled water and pelleted in a centrifuge. After three such washings and pelletings, final centrifugation was done in melted agar to give a pellet embedded in solid agar for ease of handling. The pellet was cut into blocks. Each block was fixed in buffered 2% OsO_4, washed in sodium cacodylate solution, dehydrated, and embedded in epon (made according to a procedure described by Sporn, Wanko & Dingman, 1962). Sectioning was done on an LKB-type 4801A ultramicrotome using glass knives. Material for scanning electron microscopy was thick-sectioned manually, mounted on glass coverslips with Haupt's adhesive, etched with a saturated solution of KOH in absolute ethanol, and washed in absolute ethanol. SEM viewing was done on a JSM U-3 scanning electron microscope, and TEM viewing was done on an RCA 3-G.

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[1] Nawaschin (1890) placed the spores in the smut genus *Tilletia* under *T. sphagni* Naw. Ciferri (1954) moved them to a new smut genus, *Bryophytomyces,* on the basis of spore characters. Bauch (1935) placed the spores in the discomycete genus *Helotium* under *H. schimperi* Naw. Donk (1962) found *Helotium* Fr. 1849 to be a later homonym of the agaricalean genus *Helotium* Tode *ex* Leman 1821. When Dennis (1963) moved most of the species to the genus *Hymenoscyphus* S. F. Gray 1821; however, he did not include *H. schimperi* in the transfer.

SEM viewing of intact spores showed that they are spherical and ornamented with rimmed mounds (Fig. 1). The mounds are variable in size, although there appear to be two size categories. The surface of the mounds is irregular and is especially granular inside the rims. Sectioned material under SEM shows that the rims constitute about half the height of the mounds and that the wall between the mounds is very thin in comparison with the mounds (Fig. 2). TEM viewing shows that the mounds and the wall between them are heterogeneous (Fig. 3 & 4). There is a continuous electron-translucent inner wall, parts of which, somewhat more granular than the rest, form mound-like projections which are the bases of the rimmed mounds. An electron-dense outer wall surrounding the entire spore is especially elaborate on top of the projections, where it forms the rims of the mounds.

Bauch (1935) found that fungal hyphae invading *Sphagnum* capsules and producing within the spore mother cell membranes spores called *Tilletia sphagni* Naw. were associated with hyphae on the vegetative *Sphagnum* parts bearing apothecia of *Helotium schimperi* Naw. He considered the spores to belong to the imperfect stage of *H. schimperi.* He discounted Nawaschin's (1890) conclusion that the spores were ornamented with a reticulum as in many smut teleutospores and reinterpreted the light microscopic features as a channel-network running between plates of exospore. The plates were thought to rest on top of a thin intine lamella. Also using light microscopy, later workers (Ciferri, 1954; Dickson, 1973), however, considered the ornamentation to be a reticulum and stuck with the idea that these are indeed smut spores.

This study has shown Bauch correct in rejecting the idea of a reticulum. SEM study of intact and sectioned spores shows that there is in fact a channel-network and not a raised reticulum. The rimmed mounds are not plates of exospore, however. They are projections of the inner wall with an elaboration of the outer wall on top. The supposed intine lamella is not an intine. This too is composed of both inner and outer wall.

Interestingly, a comparison of this spore ultrastructure with Graham's (1960) model for the ultrastructure of *Tilletia* spores shows the two spore types to be quite different. Based on observations of *T. contraversa* [*sic*], the smut teleutospore has an outer sheath, a reticulum layer, a lipoid containing layer, and a double endospore layer. The reticulum layer, which is responsible for spore ornamentation under light microscopy, is distinct and can be separated physically from the other layers. These spores, then, do not appear to be smut teleutospores. Most likely, as according to Bauch (1935), they are discomycete conidia of *H. schimperi.*

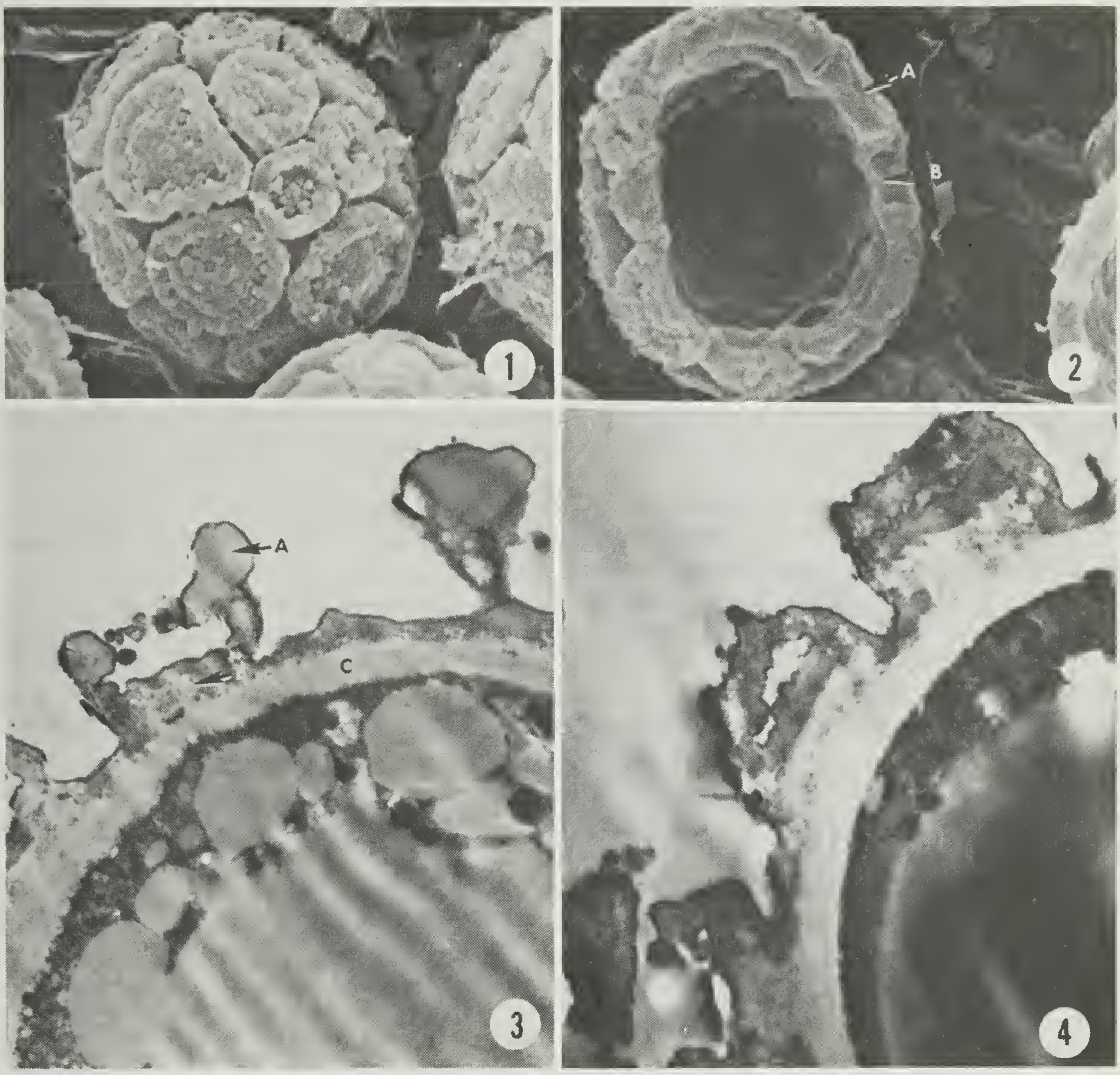

Fig. 1. SEM micrograph of an intact spore showing a regular arrangement of mounds and channel-network. ×3500. Fig. 2 SEM micrograph of a sectioned spore showing (A) mounds and (B) wall between mounds. ×3500. Fig. 3 TEM micrograph of a sectioned spore showing (A) an elaborate outer wall, (B) a granular mound-like projection and (C) the inner wall. ×9500. Fig. 4 TEM micrograph of a sectioned spore showing pronounced inner wall projections. ×11,000.

The double-wall organization of this conidium is consistent with a theory discussed by Hawker & Hendy (1963) suggesting that such double-walled conidia represent the extreme in reduction of many-spored sporangia containing single-walled spores, the conidial outer wall being homologous to the sporangial wall. Such reduction series can be seen in the Mucorales and other zygomycetous groups. Researchers such as Hawker & Hendy have argued that the presence of double-walled conidia in both the Zygomycetes and the Ascomycetes supports the view that the two groups evolved from a common ancestor. Research on the ontogeny of the two wall layers in *Helotium schimperi* may shed further light as to the applicability of this theory.

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Preliminary Announcement

THIRTEENTH INTERNATIONAL BOTANICAL CONGRESS

Sydney, Australia. 21-28th August, 1981

The Programme will consist of 12 sections–molecular, metabolic, cellular and structural, developmental, environmental, community, genetic, systematic and evolutionary, fungal, aquatic, historical, and applied botany. There will be plenary sessions, symposia, and sessions for submitted contributions (papers and posters). Chairman of the Programme Committee:–Dr. L. T. Evans.

Field Trips will include visits to arid and semi-arid regions, eucalypt forest, rain forest, health, coastal vegetation (e.g. Great Barrier Reef, mangroves) etc., and specialist trips. Chairman of the Field Trips Committee:–Prof. L. D. Pryor.

First Circular, containing details, will be mailed in August, 1979. Send your name and full address, preferably on a postcard, to ensure your inclusion on the mailing list.

Enquiries should be sent to the Executive Secretary, Dr. W. J. Cram.

Congress address–13th I.B.C., University of Sydney, N.S.W. 2006, Australia.

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STROBILUS VARIATION IN CLONES OF RUNNING PINE, LYCOPODIUM FLABELLIFORME

W. H. Wagner, Jr., and Joseph M. Beitel

Department of Botany and Herbarium
University of Michigan
Ann Arbor, 48109

Studies of natural variation have value not only *per se,* but they also bear upon taxonomic interpretations. In some cases wide variation can obscure genuinely diagnostic differences. Many clubmoss taxa are extremely variable, and this has interfered with the making of a generally accepted interpretation of species and varieties. Clubmosses vary not only in vegetative structure but also, contrary to the tradition that reproductive structures are conservative, in characters of their strobili and peduncles. The following report is of special interest for showing the potential for variability within single clones.

The genus *Lycopodium* contains members with undifferentiated sporophylls and also those with differentiated sporophylls. The former are represented in the Great Lakes area by such species as the fir clubmoss, *L. selago* L., and the shining clubmoss, *L. lucidulum* Michx. The latter are represented by the common clubmoss, *L. clavatum* L., and the bristly clubmoss, *L. annotinum* L. In *L. clavatum* the strobilus is pedunculate, and in *L. annotinum* it is sessile.

In the flat-branched clubmosses (sometimes separated as a genus *Diphasiastrum* Holub), we also find species with stalked strobili and others with sessile strobili. The most abundant and best known of the flat-branched clubmosses in our region is the running pine, *L. flabelliforme* (Fern.) Blanchard, which has long-stalked strobili, as do its near relatives, *L. complanatum* L. and *L. tristachyum* Pursh. *L. flabelliforme* has long been confused with, or made a variety of the northern running pine, *L. complanatum. L. flabelliforme* was shown by Wilce (1965) to have a number of differences from *L. complanatum,* including a branching habit that is regular and symmetrical rather than irregular and asymmetrical; lateral branches determinate rather than indeterminate; strobili commonly with sterile tips and forming a false whorl rather than dichotomously branching. Familiar manuals (e.g., Fernald, 1950; Gleason, 1952) usually make *L. flabelliforme* a variety and fail to mention the latter two characters. These and other differences, however, leave no doubt that *L. flabelliforme* is a fully distinct species. It is an endemic in the eastern part of North America, and its range extensively overlaps that of *L. complanatum,* as well as that of the ground cedar, *L. tristachyum.* All three species may occur together on the same site.

The purpose of this paper is to describe variations of strobili and peduncles of *L. flabelliforme* in two large clones. Each clone is believed to represent a single genotype on the basis of continuity within the colonies, as well as comparisons with nearby clones.

The first clone studied is in Jackson County, Michigan, in Leoni Township, sect. 13, west of Welsh Lake (Wagner 77136). On 19 October 1977, the sporangia were just beginning to dehisce. The clone extends over a second-growth area of approximately 30 by 35 feet along a north slope shaded by scattered plants of *Acer rubrum, Carya ovalis, Cornus racemosa, Juniperus communis, Prunus serotina,* and *Quercus velutina*—all common associates of running pine in southern Michigan. Other pteridophytes here are *Botrychium dissectum* and *Asplenium platyneuron.* (Close by occurs another clone roughly 20 by 25 feet in dimensions, while a little farther away there is a huge clone of the hybrid running pine, *L.* ×*habereri* House.) Figure 2 shows pairs of strobilus clusters taken from within 30-60 cm of each other on the same branch in Clone 1.

The second clone studied is in Oakland Co., Michigan, in Avon Township, in the northwest 1/4 of section 21 (Wagner 77140.5). On the day of our visit, 30 October 1977, the sporangia were still mostly undehisced. The site, kindly shown to us by Timothy J. Smart, is an exposed boggy field with groups of shrubs. The clone is approximately 25 by 10 feet, half of it exposed to full sunlight and associated with *Andropogon scoparius, Solidago canadensis,* a creeping *Rubus*, and the moss, *Polytrichum.* The other half is mainly protected under shade of *Cornus obliqua, Vaccinium corymbosum,* and other shrubs.

According to Wilce's description of *L. flabelliforme;* peduncles are "typically forking twice in close succession at the upper end . . . producing four pedicels; . . . strobili 2-4(5), typically 4, becoming 24.5(14.5-40.5) mm long exclusive of sterile tips, the sterile tips occurring on approximately 50 per cent of the specimens, and becoming up to 11.5 mm long." It should be remembered that her description is based upon hundreds of collections, and the following is based upon only two clones. The variables examined were strobilus length, strobilus number per cluster, incidence of branched strobili, presence of sterile tips, and branching pattern of the peduncle. Some of the differences in measurements between Wilce's and ours (Table 1) are probably due to the fact that hers are based on dried specimens and ours on living ones.

The shortest strobili were found in the exposed parts of Clone 2. These were nearly 5 mm shorter than those of the same clone in the shade. Strobilus number per cluster was most commonly four, and the next most common number five, except in the open in Clone 2, where it was three. The highest number was eight, three more than that given by Wilce. Although Wilce did not mention branched strobili in this species, we found a number of them, especially in Clone 2 in the shade where nearly half of the individuals had branched strobili. Branching occurred in various positions along the strobilus, sometimes near the base but more usually above the middle, as shown in Figures 1C and 2D. Sterile tips on one or more strobili were present in 17 to 78% of the clusters (Fig. 2B, C, D). Rarely the sterile tips were forked. Our experience indicates that if no sterile tips are formed prior to sporangial dehiscence, none will form at all.

We were especially interested in the "pseudo-whorled" condition in

TABLE 1. Measurements of strobilar characters of Lycopodium flabelliforme.

	Clone 1[1]	Clone 2	
		Shade[2]	Sun[3]
Strobilus length			
Range (mm.)	20-40	20-39	20-36
Mean	29.8 (± 3.6)	30.5 (± 5.3)	25.6 (± 4.2)
No./cluster & percentages			
3	1	4	13
4	74	55	78
5	25	26	9
6	0	7	0
7	0	4	0
8	0	4	0
Clusters with 1 or more branched strobili (%)	2	48	17
Clusters with sterile tips (%)			
Absent	65	22	83
Present	35	78	17
Pedicel branchings (%)			
Falsely whorled	54	30	83
Intermediate	43	18	17
Not falsely whorled	3	52	0

[1] Sample of 100 clusters
[2] Sample of 27 clusters
[3] Sample of 23 clusters

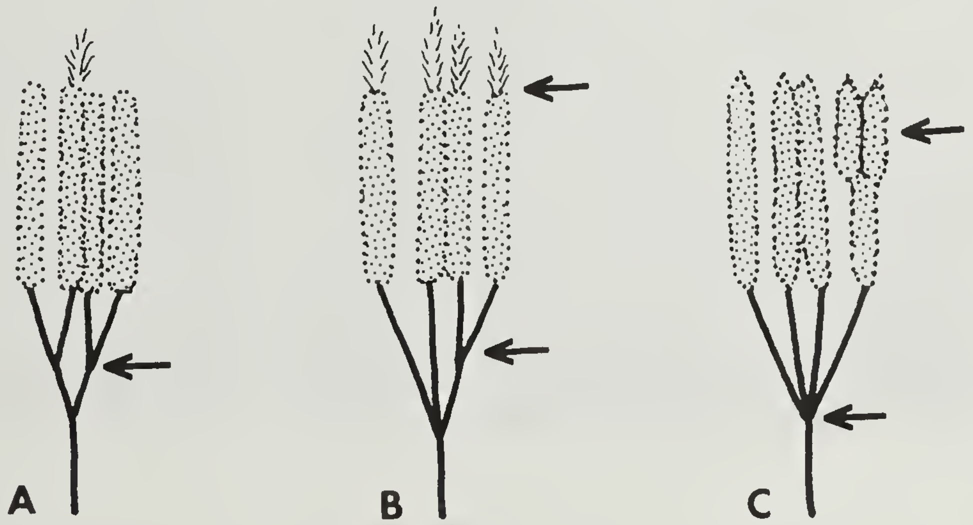

Fig. 1. Diagrams of strobilar organs in Lycopodium flabelliforme. A. Nonwhorled peduncle branching. Arrow points to dichotomies separated by definite internodes. B. Intermediate branching condition, two pedicels pseudo-whorled, two arising from a distinct branch. Upper arrow points to sterile tips of strobili. C. Falsely whorled condition, all branches of peduncle appearing to arise together, at point indicated by lower arrow. Upper arrow shows a branched strobilus.

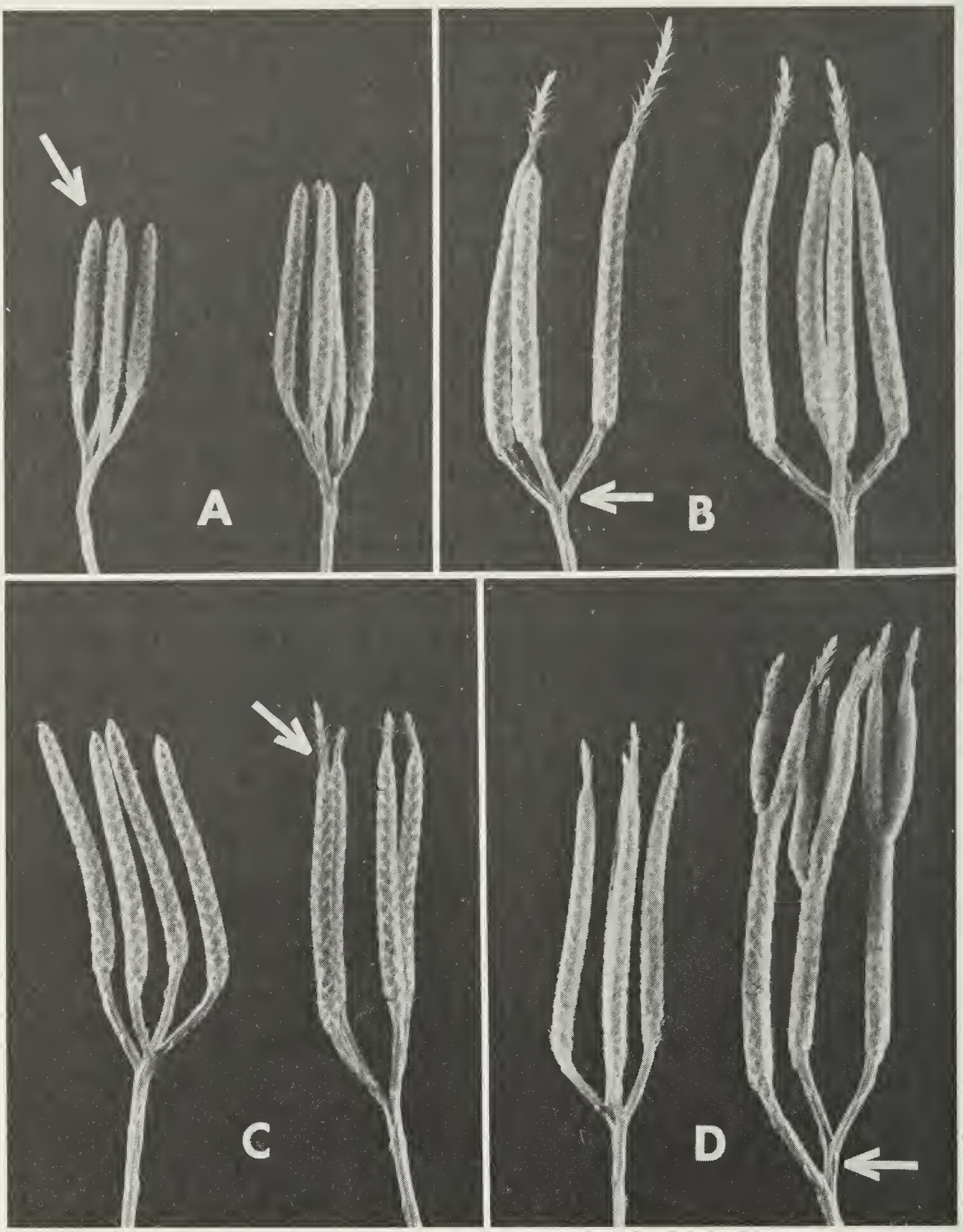

Fig. 2. Variations of strobilar organs encountered along the same branch in Clone 1. Each pair comes from a single branch. Natural size. A. Pair differing in strobilar size, pedicel branching, and number of strobili. Arrow shows tip lacking the sterile extension. B. Pair differing in number of strobili. Arrow points to falsely whorled condition involving only 3 strobili. C. Pair differing in presence of sterile tips. D. Pair differing in branching pattern of pedicels, length of strobili, and branching of strobili. Arrow points to branching pedicel showing intermediate condition.

which the forking of the second dichotomy of the peduncle occurs so close to the first that the pedicels appear to be truly whorled. The diagrams in Figure 1 show three conditions: A is found in *L. complanatum* and *L. tristachyum,* the branchings at equal intervals; C is falsely whorled; and B has one side like A and one side like B. All three were actually found in our two clones, but the falsely whorled condition is the prevalent one, with the intermediate next most common. Clone 2 shade specimens were unusual in having over half non-whorled peduncles; this seems to be correlated with the unusually high number of strobili, 26% of the clusters with five and 15% with six, seven, or eight. The highest incidence of clusters with the pseudo-whorled condition was in the open-field sample in which 83% showed this situation.

The amount of variation described here seems remarkable in that it embraces practically the total range of variation described by Wilce, even though our data came from what are presumably only two clones in southern Michigan while hers came from numerous collections scattered over eastern North America. The data suggest that there is considerable plasticity involved in the strobilar apparatus of *L. flabelliforme.* This is dramatically demonstrated in Figure 2 by the photographs of pairs of clusters which came from the same branches from Clone 1. In pair "C" one cluster on the branch has sterile tips, the other does not; and in pair "D" one has only simple strobili, and the other has branched strobili. In pair "A" the strobili of one cluster of the branch are considerably shorter than those of another cluster of the same branch.

From Clone 2 there is evidence of a strong effect from exposure: sun and shade forms of the vegetative parts of clubmosses are well known (although poorly documented), but our evidence now suggests that sun and shade forms may exist in the reproductive parts as well. Branches of the same clone growing in the sun tend to have less (but more regularly) branched peduncles with fewer strobili per cluster, the strobili being shorter and less often provided with sterile tips, than those in the shade.

Further studies of clonal variation of clubmosses should aid in understanding development in relation to habitat and should also better the taxonomy and identification of species.

We thank James Cantrall, Thomas Carlson, Tim Smart, and Kerry Walter for valuable assistance in the field.

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REVIEWS

MICHIGAN TREES WORTH KNOWING. Revised 5th ed., by Norman F. Smith. Hillsdale Educational Publishers, Inc., Hillsdale, Michigan, 49242, in cooperation with Michigan Department of Natural Resources. 1978. 88 pp. $4.50 (postpaid).

Associated with the Department of Natural Resources for 40 years, Norm Smith has devoted the first months of his "retirement" to completing an excellent new revision of his exemplary booklet. The number of large pages is increased almost 50%. A few trees, chiefly widely planted exotics, have been added in the usual format, and there are minor revisions and updating throughout the text. But the principal change is insertion of 20 pages full of color photos, covering primarily "small trees," such as blue-beech, mulberry, mountain-ash, juneberry, pin and choke cherries, redbud, "hawthorne" (as if named for an author rather than a spine), mountain and striped maples, flowering dogwood; there are a few additional color photos of tree flowers and some of winter buds, plus essays on forest succession and autumn.

The photographs—all by the author—are outstanding, as those familiar with previous editions already know. Besides closeups of leaves, flowers (or fruit), and bark, specimen trees are shown. The cover is a striking color photo-montage of leaves from at least 24 tree species. This volume is highly recommended to everyone interested in our local trees. It is beautifully and copiously illustrated, packed with readable and useful information, from the introduction on Michigan forests to the closing data on firewood. Distributional statements for a few species do need minor corrections, and one can always suggest other titles for the list of references (such as Lucy Braun's great work on the woody plants of Ohio). —E. G. Voss

BOTANICAL BEACHCOMBERS AND EXPLORERS: Pioneers of the 19th Century in the Upper Great Lakes. By Edward G. Voss. Contributions from the University of Michigan Herbarium Vol. 13. 1978. 100 pp. Herbarium, University of Michigan, Ann Arbor, 48109. $4.00 (postpaid).

This short book is indispensible to any person interested in identifying probable sources of plants collected during the early exploration of the Upper Great Lakes, especially in Michigan. It is particularly valuable in its treatment of those who were not botanists but amateurs. In addition to its usefulness to botanical researchers, the book contains a wealth of historical information of more general interest.

The survey is largely confined to the 19th century as there were few collections before 1800, and 20th century collectors generally kept better records, offering fewer problems (and were too numerous to treat in a small work). The personalities are grouped in nine chapters treated more or less chronologically, but somewhat modified by their professions or where they collected. The book is interestingly illustrated with reproductions of old sketches, portraits, maps and samples of specimen labels as well as photos of two "especially Great Lakes" plants. The bibliography is a treasure trove (7 pp.). Numerous additional references are included in footnotes (343 in all). Although interesting and occasionally humorous, the footnotes are slightly annoying unless one has the willpower to ignore them while following the general flow of the text.

As Dr. Voss indicates in the preface, this book offers a gateway to much more historical and bibliographic work. —Richard C. Harris

SOME UNUSUAL FISSIDENS COLLECTIONS FROM MICHIGAN'S UPPER PENINSULA

Janice M. Glime and Janet F. Gereau

Department of Biological Sciences
Michigan Technological University
Houghton, 49931

The Keweenaw Peninsula of Michigan is floristically unique. Wells & Thompson (1974) pointed out that the number of vascular plants occurring as disjuncts in this area is impressive, with floristic elements from boreal, temperate, arctic-alpine, and cordilleran regions. The bryophytes have similar affinities (Steere, 1937). For this reason, Keweenaw County and northern Houghton County have been studied by many bryologists (Cooper, 1913; Hermann, 1962, 1970; Whitmire, 1965; Crum, 1974; Vitt, 1974). Nevertheless, new records can still be found among the many habitats rich in bryophytes, and some (as in *Fissidens*) may show up unexpectedly.

One interesting floristic area is the rocky valley cut by Jacob's Creek just upstream from highway M-26, Keweenaw Co. (Lat. 47°25′N, Long. 88°15′W). The cooling effect of tumbling water, combined with high humidity and relative protection from trampling, contribute to a rich bryophyte flora in the stream cut. The streambed itself, where it slopes to form Jacob's Creek Falls, is richly vegetated with bryophytes, including *Fissidens grandifrons* Brid. (Glime & Keeney 113, 4 July 1976). In spite of its abundance in Jacob's Creek, this species is unreported for the Keweenaw Peninsula. Previous collections by Wheeler in Alger Co. and Nichols in Mackinac Co. represent the only Upper Peninsula records reported by Darlington (1964) and Crum (1976).

Fissidens grandifrons is typically a limestone species, growing attached to rocks or pebbles in running water and springs (Koch, 1936; Crum, 1976), but it has been reported from depths of 80-130 m in Lake Tahoe (Frantz & Cordone, 1967). Lack of limestone would explain the scarcity of the species in the Upper Peninsula; its abundance on the basalt of the Jacob's Creek streambed is unusual.

Fissidens fontanus (B.-Pyl.) Steud. has been found at several locations in the Lower Peninsula, where it grows submerged in brooks in inundated areas (Crum, 1976). It also occurs at depths of 6-10 m in the Great Lakes (Hiltunen, 1966). In northern Europe it occurs in shallow water on a variety of substrates (loose mud, hard bottom, other mosses, and mollusk shells), but rarely on wood (Lohammar, 1954). Although the species is known from Canada to the north and from the Lower Peninsula to the south, it has not previously been reported for the Upper Peninsula of Michigan. We found it in two localities in Houghton County, where it grew attached to wood and was situated barely beneath the springtime water surface. In a pond (or bay) of the Pike River (Lat. 47°1′N, Long. 88°29′W) on the eastern edge of Chassell, it was growing on the wooden pilings of an old dock (Trynoski & Glime, 7 May 1976), and in Dollar Bay (Lat. 47°7′N, Long. 88°30′W) of the Keweenaw Waterway it was on a submersed log (Glime 109, 8 May 1976). Although the plants were present in these locations throughout the summer and fall of 1976, they could not be found in 1977. Lower water levels had left the mosses stranded by the end of the summer and fall. Lohammar (1954) suggested that *F. fontanus* prefers eutrophic waters and is intolerant of freezing. Perhaps these slightly eutrophic waters were suitable for the species, but freezing while they were out of water in the early winter of 1976-77 may have destroyed them.

Voucher specimens of Glime 109 and 113 are in the University of Michigan Herbarium. We thank Dr. Howard Crum for verifying our determinations.

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BOLETUS SPHAEROCYSTIS, A LITTLE-KNOWN EDIBLE BOLETE

Nancy S. Weber
Herbarium, University of Michigan
Ann Arbor, 48109

During a special interest course in mushroom identification at Nicolet College and Technical Institute, Rhinelander, Wisconsin, the staff was unable to name a bolete that was brought in for determination. The fungus, eaten regularly by several people in the area, proved to be *Boletus sphaerocystis* Smith & Thiers (Fig. 1), previously known from a single collection from southeastern Michigan (Smith & Thiers, 1971). An expanded description of the species is given here and its edibility discussed:

Pileus (as dried) 4-8 cm broad, when fresh light crust brown, unpolished to finely velvety, not viscid, even, broadly convex. Flesh firm, pallid cream color, not changing to blue when broken or bruised. Tubes dull olive ochre, not staining or changing color when bruised or broken, or merely becoming brownish, depressed around the stipe apex.

Stipe (as dried) 5-9 cm long, 0.4-1 cm broad, when fresh terete, creamy yellow with rosy red tints developing near the apex and base in age, not staining blue when injured; surface pruinose.

Spore deposit dull clay color. Spores 12-16 × 4-5 µm, inequilateral in profile, subfusoid in face view, not truncate, with a distinct suprahilar depression, non-amyloid,

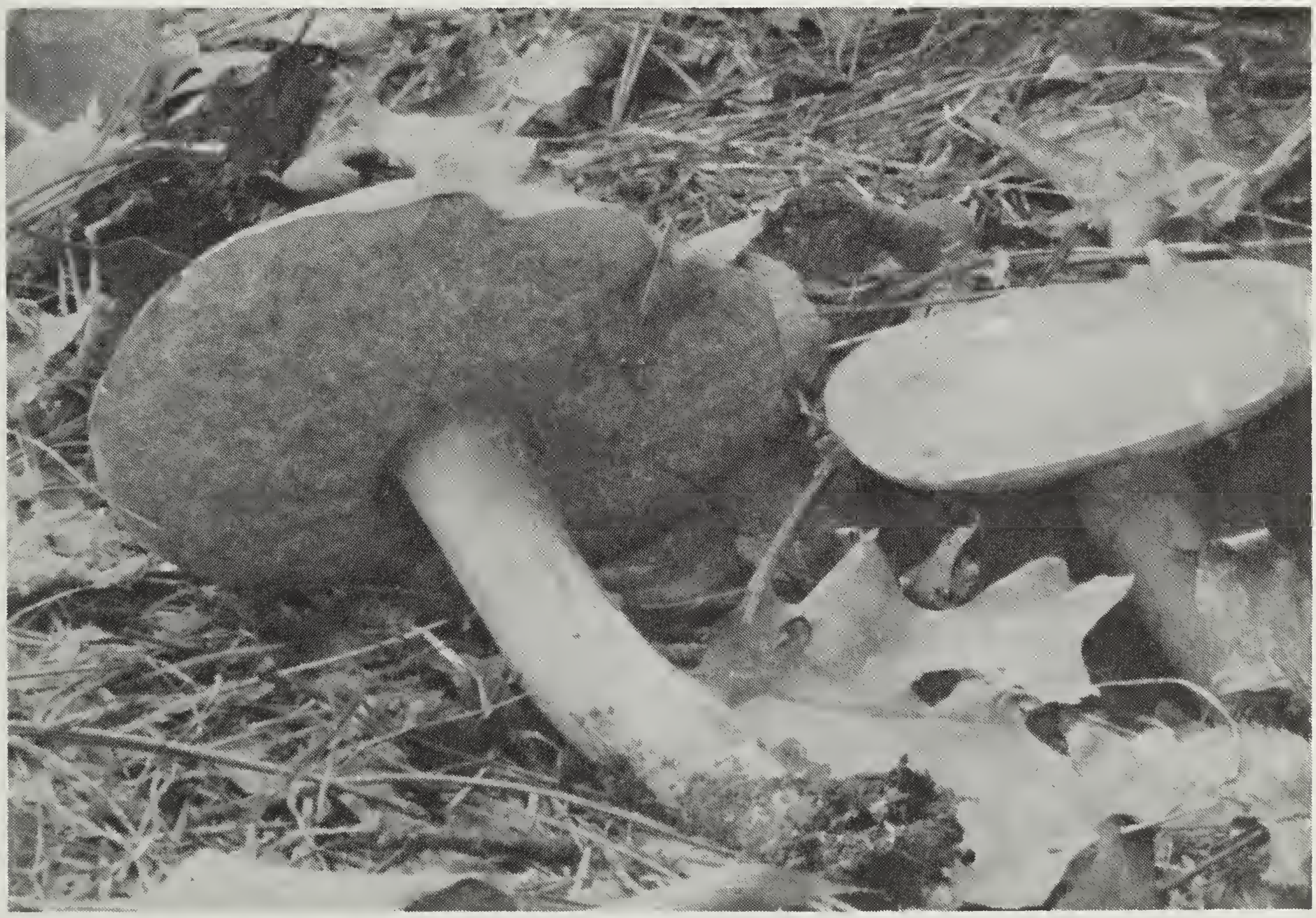

Fig. 1. *Boletus sphaerocystis* (photograph by Mrs. Jena Jirak).

light ochre in KOH. Basidia 4-spored, about 24 × 9 μm. Neither pleurocystidia nor cheilocystidia observed. Tube trama weakly divergent to regular as revived, gelatinizing in KOH. Pileus trama of loosely interwoven, thin-walled hyphae; clamp connections not observed. Pileus cuticle a trichoderm with the cells variously inflated (to ± isodiametric) and thus appearing to form a cellular zone 2-5 cells thick; end cells clavate to subglobose; cuticle not obviously viscid. Clamp connections scattered on hyphae of stipe cortex. Caulocystidia clustered, clavate to clavate-mucronate, intermixed with basidia, 15-45 × 9-18 μm, content pale yellow in KOH.

The above description is based on material communicated by an instructor at Nicolet College. The specimens, collected near Rhinelander, Wisconsin, in the fall of 1975, are deposited in the Herbarium of The University of Michigan as N. S. Weber 4362 and 4363. They were found under mixed hardwoods and balsam fir. One collector reported that it typically fruits from July into August (or as late as early September on occasion) on south-facing slopes, while another collector found it on slopes with a southern or southeastern exposure in hardwoods or on upland, well drained flats. The Wisconsin material corresponds to the holotype of *B. sphaerocystis* in most respects but has slightly smaller spores (14-18 × 5-6.5 μm for the holotype). The characteristic pileus cuticle is illustrated in Fig. 2, and Fig. 3 shows the spores of the holotype and the Wisconsin material, respectively.

Mrs. Jena Jirak of Woodruff, Wisconsin, first brought this species to the class. She reported that her family has eaten it for several years. Whenever she eats it, she develops symptoms of an allergic reaction characterized by swelling which begins with her eyelids. No other members of the family were reported to have this reaction. Another resident of the area, Mr. Pat Folgert, also

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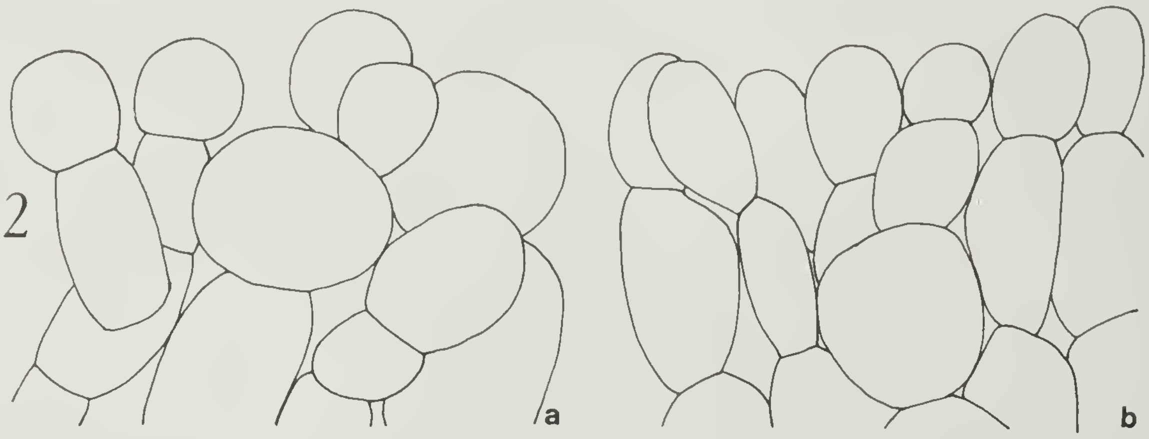

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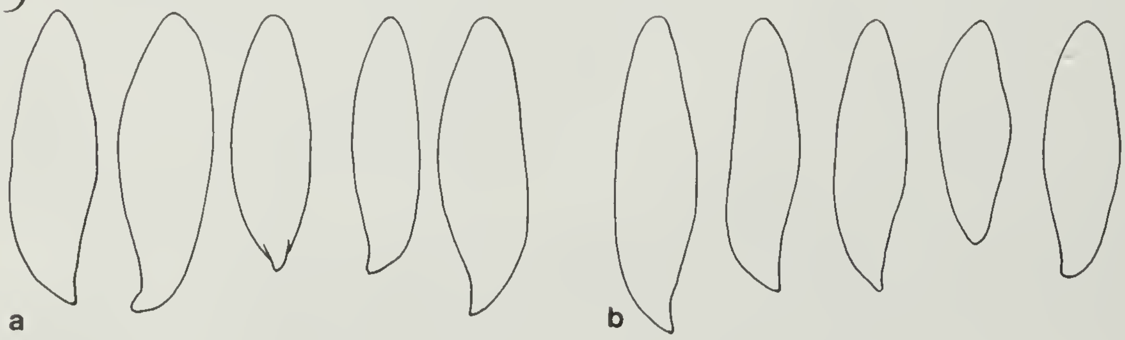

Fig. 2. Pileus cuticle of *Boletus sphaerocystis.* a. Holotype, Smith 63279; b. Weber 4363.
Fig. 3. Spores of *Boletus sphaerocystis.* a. Holotype, Smith 63279; b. Weber 4363.

reported that his family has eaten this species for several years, alone and in combination with other boletes, and no ill effects have been noted. It occurs in abundance some years and is sufficiently common in that area to attract attention as a possible item of food. The pattern of reaction to *B. sphaerocystis* is not uncommon among people who eat wild mushrooms. Similar reactions are known for *Boletus edulis* and *Suillus americanus.* Those who wish to experiment with eating *B. sphaerocystis* should proceed with caution to determine whether they are sensitive to it.

The important field characters of *Boletus sphaerocystis* are the dry, tan to light-brown, smooth pileus; unchanging flesh and tubes; and the creamy to bright-yellow pruinose stipe with red tones at the base and sometimes at the apex. A check of spore size and structure of the pileus citicle will aid in identification. The species is related to *B. subglabripes,* but the latter has spores 11-14 X 3-4 μm, numerous cheilocystidia, and a more distinct trichoderm in the pileus cuticle. Furthermore, it is yellower on the pileus, with bright-yellow tubes, and has a yellow stipe which only occasionally has reddish stains at the base.

I would like to thank Dr. Robert Shaffer, Director, for the use of the collections and facilities of the University of Michigan Herbarium; Dr. Alexander H. Smith for advice and helpful suggestions; and Dr. Johanna Clausen of Nicolet College and Technical Institute for submitting the specimens. The administration of Nicolet College deserves special thanks for funding the mushroom identification course.

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THE HANES FUND AND THE MICHIGAN FLORA PROJECT

Approximately 10 years ago the Hanes Fund was established in accordance with the will of Florence N. Hanes "to be used . . . for the publishing of a Flora of the State of Michigan or should the publishing of a Flora of the State of Michigan have been accomplished prior to my death, then I direct that . . . the fund . . (be utilized) . . for the further study of the local vascular plants . . . " The fund is administered by three court-appointed Trustees who currently are Harriette Bartoo (Kalamazoo), W. H. Wagner (University of Michigan), and William J. Gilbert (Albion College.)

The cost of publication of the first volume of MICHIGAN FLORA (part I, Gymnosperms and Monocots) was underwritten by the Hanes Fund. It is anticipated that at least part of the cost of future volume(s) also will be underwritten. In the meantime, the Trustees of the Hanes Fund wish to announce the availability of small grants for incidental expenses in connection with well-planned projects that will make a definite contribution to the Michigan Flora Project. Maximum size of the grants will be $400 with the average grant between $100 and $200. Supported projects must deal with the vascular plants of Michigan. First sets of collected plants must be deposited at the Herbarium of the University of Michigan. Amateur and professional botanists, as well as advanced college students, are eligible to apply for the grants. Proposals should be submitted to The Hanes Fund Trustees, c/o Dr. William J. Gilbert, Dept. of Biology, Albion College, Albion, Mich. 49224. Proposals should contain a clear description of the proposed project, its time-table, and a detailed listing of anticipated expenses. The proposals will be reviewed for possible funding by the Trustees of The Hanes Fund and their consultants.

MICHIGAN PLANTS IN PRINT

New Literature Relating to Michigan Botany

C. JOURNAL ARTICLES

Barkworth, Mary E. 1978. A taxonomic study of the large-glumed species of Stipa (Gramineae) occurring in Canada. Canad. Jour. Bot. 56:606-625. [Distribution maps include occurrences of *S. comata* and *S. spartea* in Michigan, one of the former distinctly farther north than previously known records—but no data are given.]

Barnes, Burton V. 1976. Succession in deciduous swamp communities of southeastern Michigan formerly dominated by American elm. Canad. Jour. Bot. 54:19-24. [Study in Washtenaw and Oakland counties.]

Barstow, Jeanne M., & Frederic H. Erbisch. 1977. Effects of acute gamma radiation and winter temperature-light conditions on photosynthesis of Cladonia mitis. Bryologist 80:83-87. [Material studied was from Keweenaw Co.]

Belling, Alice J., & Calvin J. Heusser. 1975. Spore morphology of the Polypodiaceae of northeastern North America. II. Bull. Torrey Bot. Club 102:115-127. [The material studied, fully described and illustrated, of two species was from Michigan: *Asplenium trichomanes* and *Cryptogramma crispa* var. *acrostichoides.*]

Bowler, P. A. 1977. Ramalina thrausta in North America. Bryologist 80:529-532. [Southernmost stations for this lichen are cited and mapped from Chippewa Co. and Isle Royale.]

Bowler, P. A., & P. W. Rundel. 1978. The Ramalina farinacea complex in North America: Chemical, ecological and morphological variation. Bryologist 81:386-403. [Two chemotypes of the species are mapped and cited from Isle Royale.]

Canne, Judith M. 1977. A revision of the genus Galinsoga (Compositae: Heliantheae). Rhodora 79:319-389. [One representative specimen is cited from Michigan for each of the weedy species which are shown on generalized maps as occurring throughout the state: *G. quadriradiata* (previously known as *G. ciliata*) and *G. parviflora.*]

Catling, Paul M. 1976. On the geographical distribution, ecology and distinctive features of Listera ×veltmanii Case. Rhodora 78:261-269. [Adds an Isle Royale record to known occurrence in Michigan, where the type locality is near Grand Marais.]

Catling, Paul M. 1978. Taxonomic notes on Spiranthes casei Catling & Cruise and Spiranthes ×intermedia Ames. Rhodora 80:377-389. [Some of the drawings of lip and lateral petal of *S. casei* are from Michigan material.]

Crum, Howard, & Yvonne Mescall. 1977. Grimmia pulvinata in eastern North America. Bryologist 80:152-153. [First Michigan record is from Emmet Co.]

Crum, Howard, & Jerry A. Snider. 1977. Sphagnum quinquefarium in the American West. Bryologist 80:156-158. [Occurrence in Mackinac Co. is also cited.]

DiCosmo, Frank. 1978. A revision of Corniculariella. Canad. Jour. Bot. 56:1665-1690. [Three of the 7 recognized species are known from Michigan (2 of them including holotypes), and so also is *Foveostroma drupacearum.*]

Dorn, Robert D. 1975. A systematic study of Salix section Cordatae in North America. Canad. Jour. Bot. 53:1491-1522. [Based mostly on western material—none from the range of *"S. syrticola,"* which is not even mentioned; map includes occurrences of *S. glaucophylloides* in Michigan.]

Esslinger, Theodore L. 1977. A chemotaxonomic revision of the brown Parmeliae. Jour. Hattori Bot. Lab. 42:1-211. [Of the 107 species recognized in this large group of lichens, the occurrence of 13 is mapped in Michigan, with discussion of atypical Michigan specimens of one of them *(P. subolivacea)*; one additional species *(P. trabeculata)* is cited from Isle Royale.

Esslinger, Theodore L. 1977. Studies in the lichen family Physciaceae. I A North American species. Mycotaxon 5:299-306. [Distribution maps show occurrence of the new species, *Physcia adiastola,* and of *P. rubropulchra* in Michigan.]

Esslinger, Theodore L. 1978. Studies in the lichen family Physciaceae. II The genus Phaeophyscia in North America. Mycotaxon 7:283-320. [Distribution maps show occurrence of *P. cernohorskyi, P. imbricata,* and *P. pusilloides* in Michigan; Michigan collections are cited for *P. hispidula* and *P. sciastra.*]

(continued on pg. 36)

OBSERVATIONS ON HOUGHTON'S GOLDENROD (SOLIDAGO HOUGHTONII)

J. K. Morton

Department of Biology
University of Waterloo
Waterloo, Ontario

Houghton's Goldenrod is a very distinctive large-flowered species somewhat similar to *Solidago ohioensis* but differing in its narrower leaves, much larger heads (capitula), and pubescent inflorescence. The species is named *S. houghtonii* gray after the Michigan geologist and botanist Douglass Houghton, who discovered it in 1839 in Mackinac County on the northern shores of Lake Michigan. It is a Great Lakes endemic, remarkable for two reasons: Firstly, it is confined to a small part of the Great Lakes region—the northern shores of Lakes Michigan and Huron. Second, unlike many Great Lakes endemics, it is very distinct (fig. 1) and not just a local variant of a species which occurs elsewhere. This immediately raises the question of how Houghton's Goldenrod evolved, for the region was covered by glacial ice and glacial lakes until about 10,000 years ago. The origin of the species may be even more recent because this region was subsequently covered by post-glacial Lake Nipissing until about 5,000 years ago, whilst the dunes and shore line on which it now grows are probably no more than 3,000 years old.

Houghton's Goldenrod is closely associated with, and almost entirely confined to, the shores of the Great Lakes, but it shows a peculiar and interesting dichotomy in the type of habitat in which it grows. It is locally common around the northern shores of Lake Michigan and the northwestern shores of Lake Huron. In these localities, as far east as Cockburn Island, it grows in moist sandy depressions behind the dunes. Recently the species has been found to occur farther east in Canada, in the eastern part of the Manitoulin District and on the Bruce Peninsula near Cabot Head. In these localities it grows on seasonally wet limestone pavement. There appear to be no morphological differences between the plants from these two habitats. I only know of one inland colony, from the middle of the northern Lower Peninsula in Crawford Co. An examination of the specimen on which the record is based (Voss 11008, MICH, TRT) confirms that it is *S. houghtonii* and not the very similar hybrid between *S. ohioensis* and *Aster ptarmicoides.* The first collection of this species from Canada was made by Grassl on Cockburn Island in 1932 (Grassl 2362, MICH). Though this was recorded by Guire & Voss (1963) on a distribution map, the species was not noted as new to Canada. In 1970 I found the plant near Cabot Head on the Bruce Peninsula (Morton NA 4358, WAT, CAN, TRT, SFS), and more recently it has proved to be abundant on Great Cloche Island, the adjoining part of Manitoulin Island, and several nearby smaller islands. This appears to be the extent of the total range of *S. houghtonii,* a range which is illustrated on the accompanying

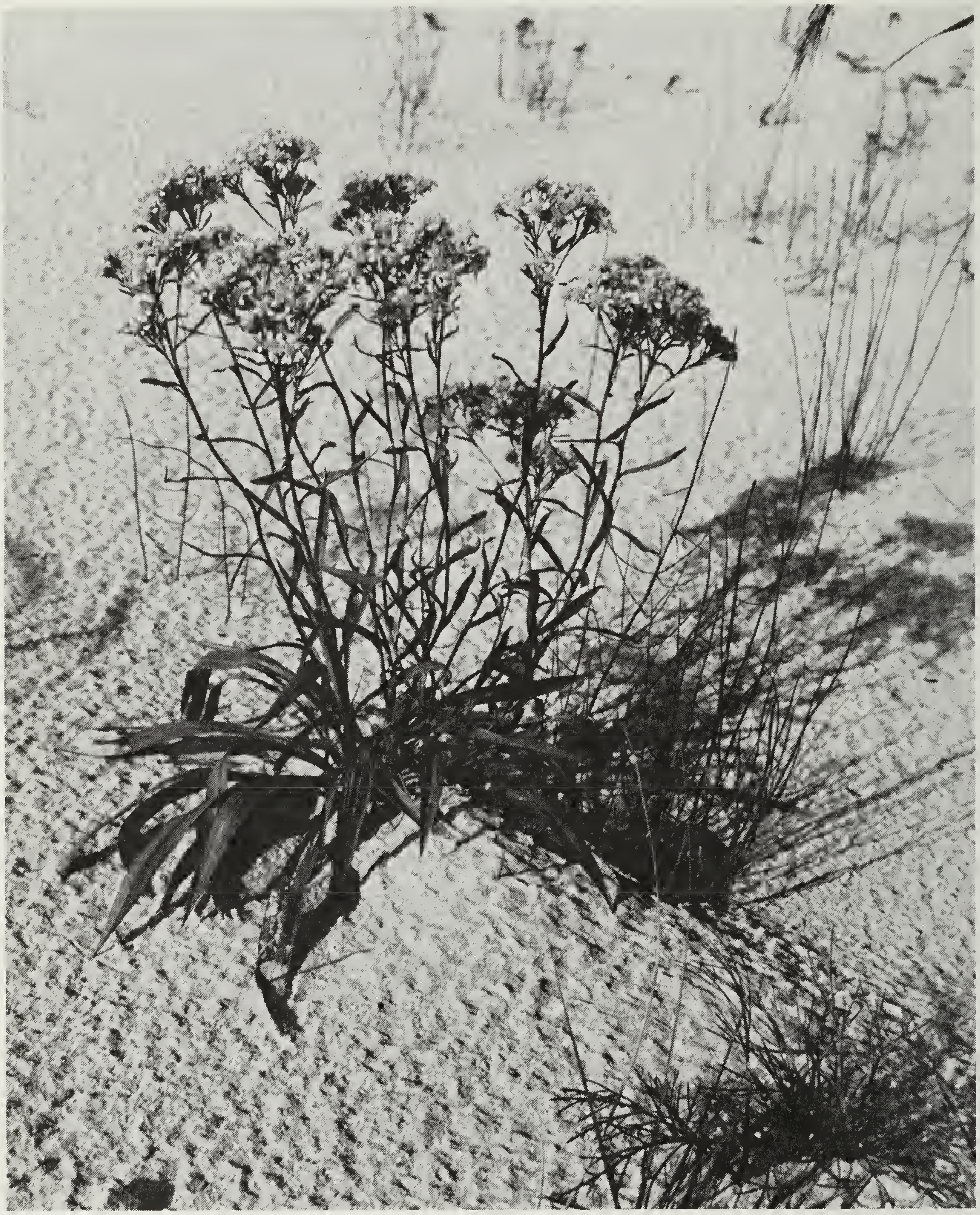


Fig. 1. *Solidago houghtonii* photographed near the type locality on the shores of Lake Michigan west of Epoufette, Mackinac Co, August 1977.

map (fig. 2), based on specimens in the following herbaria: WAT, MICH, UMBS, TRT, CAN, and NY. Records of this species from Genesee Co. New York, are referable to an *Aster/Solidago* hybrid which is discussed in this paper.

Though *S. houghtonii* is well marked and distinct, confusion is possible with what is probably its nearest relative, *S. ohioensis,* particularly with

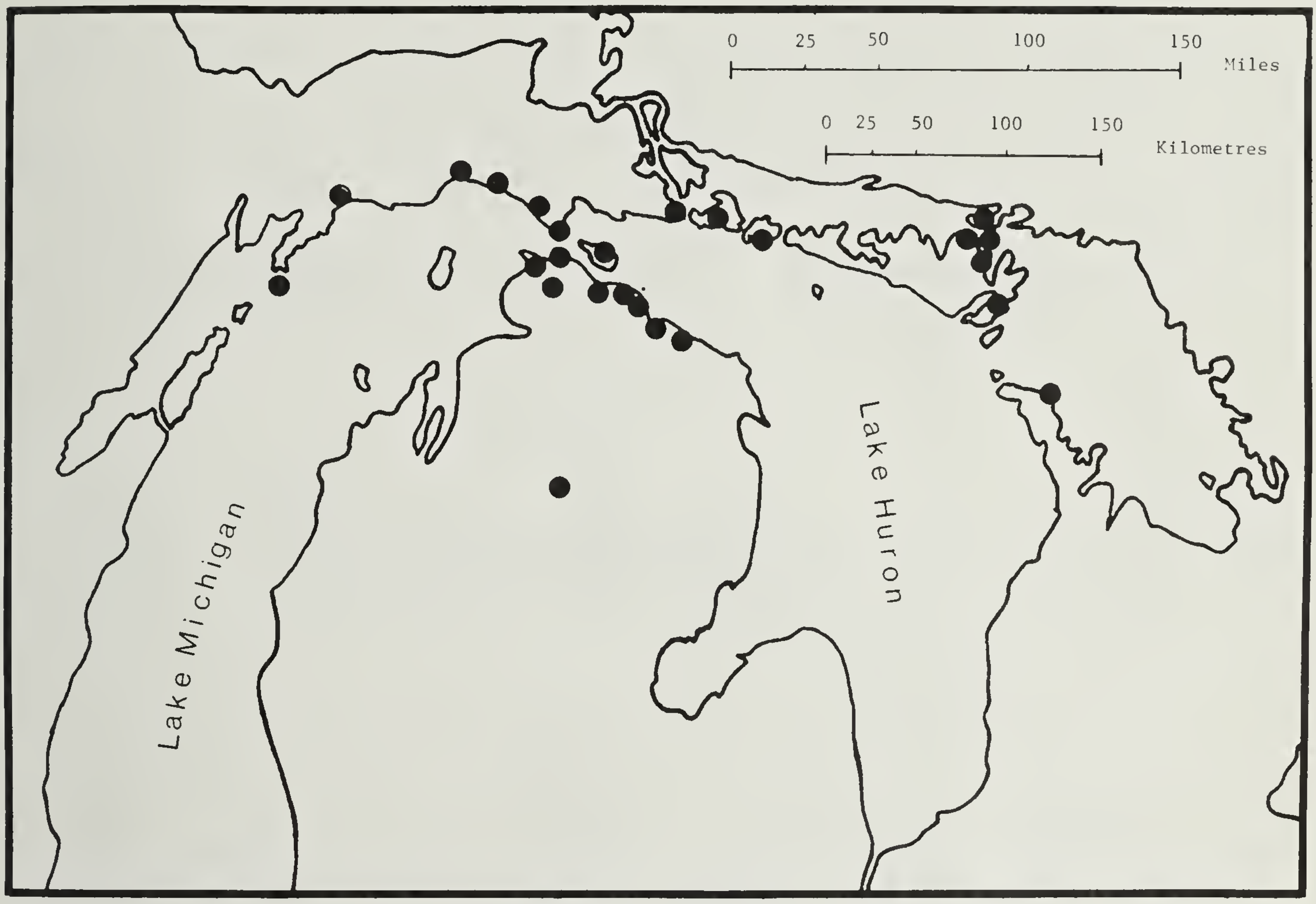


Fig. 2. The distribution of *Solidago houghtonii.*

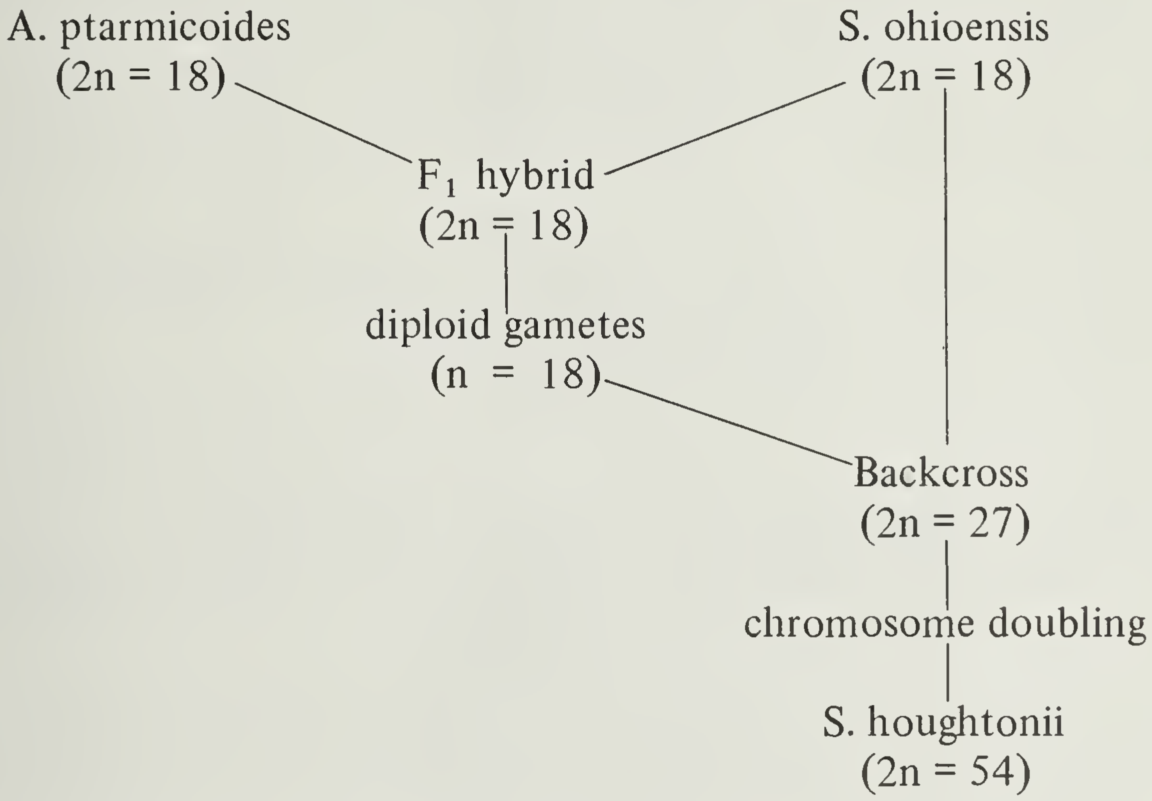
narrow-leaved forms of this species which are past flowering and in which the pappus has elongated making the capitula appear larger than they really are. However, the size of the phyllaries (bracts of the capitulum), together with the presence of a scabrid pubescence on the branches of the inflorescence, always serve to distinguish *S. houghtonii.* Greater difficulties arise with hybrids between *Aster ptarmicoides* and *Solidago ohioensis.* When fresh, these have pale yellow flowers which immediately separate them from the rich golden yellow of *S. houghtonii,* but in dried material flower color is not usually well preserved. These hybrids have a pubescent inflorescence, and identification of herbarium material may require careful examination and measurement of several characters. Table 1 gives the main differences between *S. houghtonii* and the other species and hybrids with which it may be confused.

Did Houghton's Goldenrod evolve in the Great Lakes region since deglaciation, and if so, from which related species did it evolve? Or did it move into the area from elsewhere and the original populations, outside the Great Lakes region, die out? These are two of the interesting questions posed by this species. Probable clues to its evolution may be found in its chromosome number and its close similarity to hybrids between *Solidago ohioensis* and *Aster ptarmicoides.* These hybrids are diploid ($2n = 18$) like the parent species, whereas *S. houghtonii* is a polyploid ($2n = 54$). This suggests the possibility that *S. houghtonii* may have arisen and gained fertility through chromosome doubling (amphidiploidy) in such a hybrid. Another clue is to be found in the unusual shape of the pappus bristles which are slightly clavate

TABLE 1. A comparison of S. HOUGHTONII and its allies.

	Aster ptarmicoides	Hybrids between 1 & 3	Solidago ohioensis	Solidago houghtonii
Plant height (normal range)	20-30 cm	30-45 cm	40-50 cm	35-50 cm
Width of rosette leaves (*not* lower stem leaves)	up to 10 mm	up to 10 mm	15-45 mm	up to 22 mm
Pubescence of inflorescence	scabrid-pubescent	thinly scabrid-pubescent	glabrous	scabrid-pubescent
Angle of main branches of inflorescence	exceeding 45°	c. 45°	35-45°	30-45°
Length of capitulum				
a) to tip of phyllaries	5-6 mm	4-5.5 mm	4-5 mm	5.5-8 mm
b) to top of disc florets	7-9 mm	5.5-7 mm	4-7 mm	8-10 mm
Number of capitula per primary branch of inflorescence	1-6	1-17	10-54	2-18
Shape of inner phyllaries	lanceolate	lanceolate to narrowly elliptic	narrowly elliptic to oblanceolate	oblanceolate
Shape of tip of inner phyllaries	narrowly triangular obtuse	triangular obtuse	round	round to slightly triangular
Midrib of phyllaries	opaque and diamond shaped at tip	opaque and diamond shaped at tip	linear, often obscure	obscure
Total number of florets	c. 47	28-49	c. 27	c. 19
Number of ray florets	17	10-12	8	6
Flower color	white	pale yellow	gold	gold
Width of ligule	2 mm	1-1.3 mm	0.8 mm	1.5 mm
Length of ray florets (incl. ovary)	8-9 mm	6-7.5 mm	5 mm	10 mm
Length of disc florets (incl. ovary)	6.5 mm	4-6 mm	4.5 mm	8 mm
Pappus bristle, shape at tip	many bristles clavate & plumose	slender & pointed or some slightly clavate & plumose	all slender & pointed	many bristles slightly clavate & plumose
Diameter of pollen	0.09 mm	0.09 mm	0.09 mm	0.11 mm
Length of "seed"	2-2.5 mm	c. 1.5 mm (but prob. sterile)	1.5-2 mm	2.5-3 mm
2n	18	18	18	54

(shaped like a bottle brush) and intermediate between those of *Aster ptarmicoides* and a *Solidago.* Thus Houghton's Goldenrod probably evolved in the Great Lakes region since deglaciation, from hybrids between *Aster ptarmicoides* and *Solidago ohioensis,* with subsequent chromosome doubling. This mode of origin is represented in the following diagram:


A. ptarmicoides
(2n = 18)
S. ohioensis
(2n = 18)
F_1 hybrid
(2n = 18)
diploid gametes
(n = 18)
Backcross
(2n = 27)
chromosome doubling
S. houghtonii
(2n = 54)

Experimental work is needed to see whether Houghton's Goldenrod can be synthesized in the above manner. However, nature has provided us with the first stage of the experiment in the form of F_1 hybrids between *Aster ptarmicoides* and *Solidago ohioensis.* These have frequently been collected and have been given several names, including *Diplopappus lutescens* Lindley ex DC. 1836, *Aster lutescens* (Lindley) Torrey & Gray 1842, *Solidago* ×*krotkovii* Boivin 1967, and *Solidago lutescens* (Lindley) Boivin 1972 (see Bernard 1969).

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(continued from pg. 30)

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Harriman, Neil A., & Darrell Redmond. 1976. Somatic chromosome numbers for some North American species of Juncus L. Rhodora 78:727-737. [Includes counts on Michigan material (fully cited) of *J. inflexus* and *J. articulatus*—both of them the first counts on North American material.]

Hausen, B. M. 1978. On the occurrence of the contact allergen primin and other quinoid compounds in species of the family of Primulaceae. Arch. Dermatol. Res. 261:311-321. [Among material screened was *Primula mistassinica* from Duncan Bay [Cheboygan Co.], a species having been reported to cause dermatitis.]

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Horton, Diana G., & Dale H. Vitt. 1976. Morphological characters, relative to distribution, and taxonomic considerations of the genus Climacium in North America. Canad. Jour. Bot. 54:1872-1883. [Two species of this moss genus occur in North America, both in Michigan as shown by outline distribution map and maps of morphological features.]

Ireland, Robert R. 1978. Trichodon in North America. Bryologist 81:150-154. [*T. cylindricus* mapped and cited from Keweenaw Co. (Mt. Bohemia).]

Jones, Almut G. 1978. The taxonomy of Aster section Multiflori (Asteraceae) I. Nomenclatural review and formal presentation of taxa. Rhodora 80:319-357. (One representative specimen of *A. ericoides* ssp. *ericoides* and three of *A.* ×*amethystinus* are cited from Michigan, the former from Washtenaw Co. and the latter all from Wayne Co.]

Kohli, B., & John G. Packer. 1976. A contribution to the taxonomy of the Potentilla pensylvanica complex in North America. Canad. Jour. Bot. 54:706-719. [*B. bipinnatifida* the only species mapped in Michigan (Upper Peninsula, but not Keweenaw Peninsula).]

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Moldenke, Harold N. 1975. A fifth summary of the Verbenaceae, Avicenniaceae, Stilbaceae, Dicrastylidaceae, Symphoremaceae, Nyctanthaceae, and Eriocaulaceae of the world as to valid taxa, geographic distribution, and synonymy Supplement 5. Phytologia 31:374-412. [Corrects listings for two species in Michigan.]

(continued on pg. 42)

INVESTIGATIONS ON THE FRESHWATER ALGAE OF WISCONSIN. II

Louis L. Lipsey, Jr.

Department of Botany
Southern Illinois University
Carbondale, 62901

Mason G. Fenwick

Department of Biological Sciences
Northern Illinois University
DeKalb 60115

In a previous paper (1978) we presented a checklist to the phytoplankton diatoms of High Lake, Vilas County, Wisconsin. This paper presents information on patterns of distribution and relative abundance of the major planktonic diatoms found in High Lake.

Surface and bottom plankton diatom samples were collected from 13 sampling stations. Eight stations were situated within the littoral zone(s) of the lake and five within the limnetic zone. Collecting methods, locations, and dates have been described previously (Lipsey & Fenwick, 1978). Statistical analysis of the data was accomplished using a 3-way ANOV program (program AVAR 23) developed by Veldman (1967).

Asterionella formosa Hass.

This is one of the most easily recognized species found in High Lake. It was most abundant in May (Fig. 1), when its mean concentration was 11.49 ± 2.07 X 10^3 cells/1. No significant differences were found in the concentration of these cells between surface and bottom samples, nor were there any between limnetic and littoral zones. This indicates that the distribution of *A. formosa* was probably uniform throughout the water column at this time. The same general distribution also occurred in July and August, although the concentration of this species had fallen to 3.47 ± 2.07 X 10^3 cells/1 and 0.67 ± 2.07 X 10^3 cells/1, respectively.

Cyclotella stelligera (Cl. & Grun.) V.H.

This species was found in minimal concentrations in May (Fig. 1); however, by July its numbers had increased to 15.49 ± 1.10 X 10^3 cells/1. In addition, the concentrations of *C. stelligera* were significantly greater in limnetic sampling stations (P = 0.0275) than they were in littoral stations (i.e., 17.60 ± 1.77 X 10^3 cells/1 compared to 13.38 ± 1.40 X 10^3 cells/1). This same phenomenon occurred in August even though the overall concentration of *C. stelligera* had diminished considerably (Fig. 1). Green (1976) reported that turbulence is needed to keep *C. stelligera* in suspension. It is quite possible, therefore, that aquatic macrophytes are reducing the turbulence in

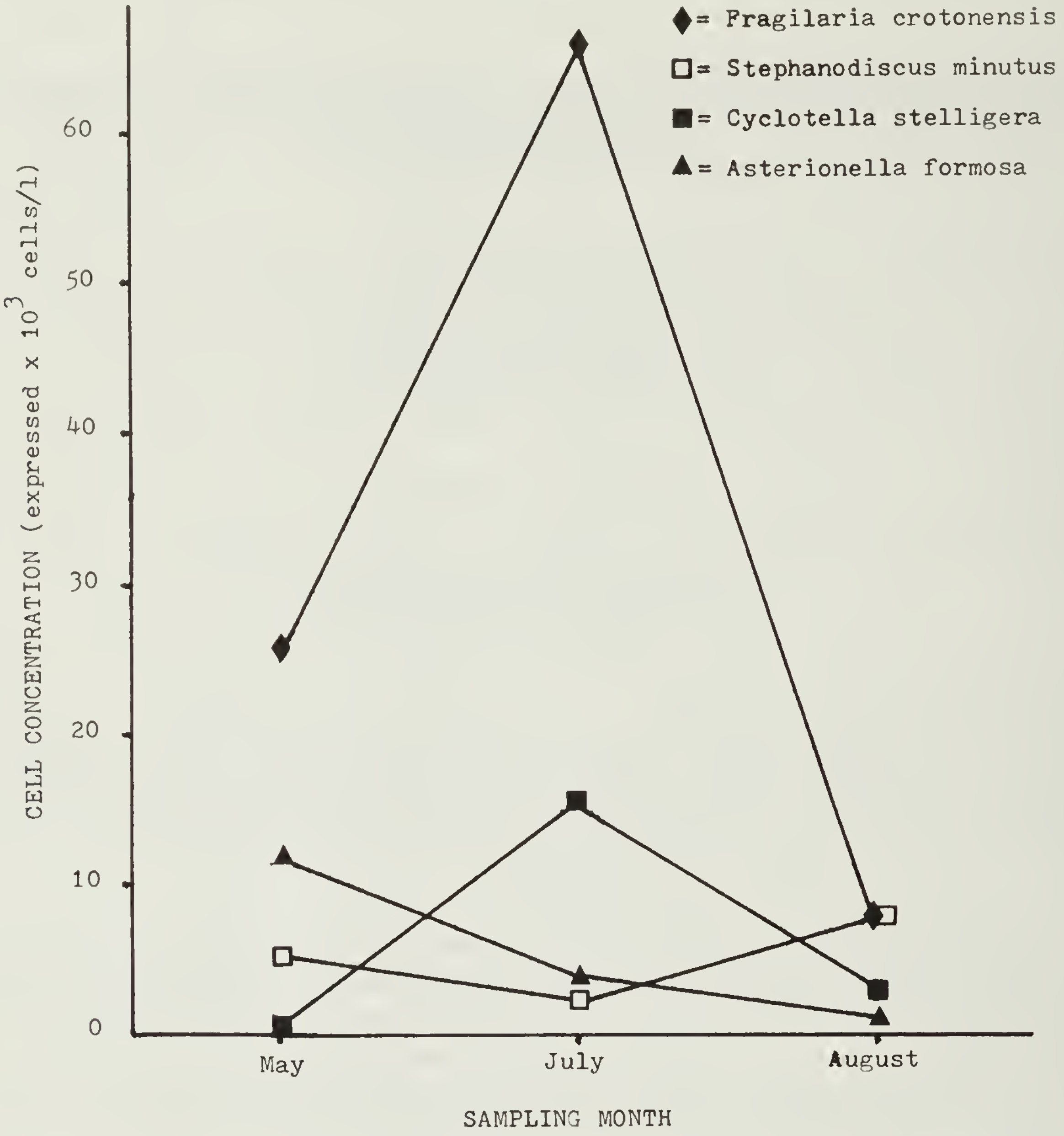

Fig. 1. Mean cell concentrations of *Asterionella formosa, Cyclotella stelligera, Fragilaria crotonensis,* and *Stephanodiscus minutus* in May, July, and August (1975).

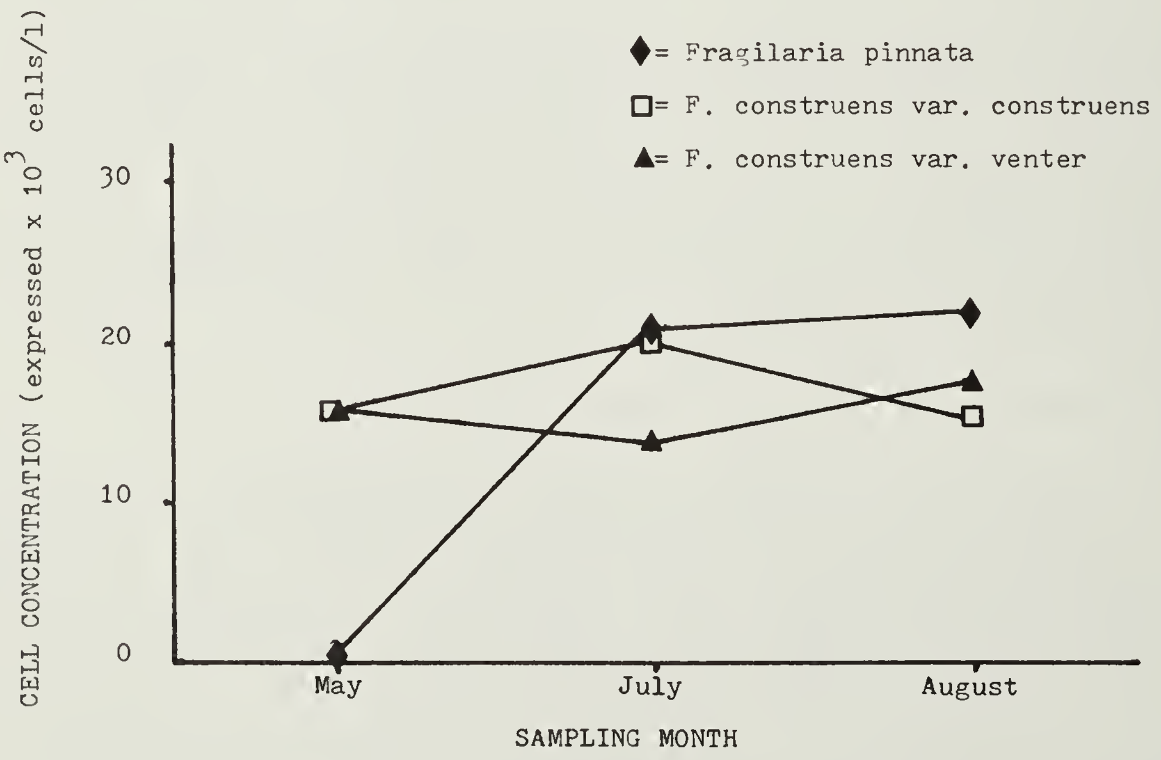

Fig. 2. Mean cell concentrations of *Fragilaria pinnata, F. construens* var. *construens* and *F. construens* var. *venter* in May, July, and August (1975).

the littoral zone and further inhibiting the growth and development (reducing cell numbers) of *C. stelligera* in this region.

Fragilaria construens (Ehr.) Grun. var. *construens*

This taxon was found in abundance during the entire study. Its concentrations were fairly constant from one sampling date to the next (Fig. 2). Figure 2 is a bit misleading, however, since further data analysis revealed the following trends: (1) There was a significant difference in the concentrations of *F. construens* in surface and bottom samples at all three sampling dates (P = 0.0696); (2) the concentration of cells were significantly higher in the littoral than in the limnetic zone (P = 0.0138); and (3) as should be expected, the concentration of *F. construens* differed significantly in surface and bottom samples from limnetic and littoral zones (P = 0.0376).

During the entire study *F. construens* was found in greatest abundance in bottom samples taken from the littoral zone, as indicated in Table 1)., which also reveals that the concentration of *F. construens* in surface samples from littoral and limnetic zones and in bottom samples from the limnetic zone is much lower than that in the bottom-littoral samples.

Fragilaria construens var. *venter* (Ehr.) Grun.

Like the nominate form, the variety concentration was more or less constant from one sampling date to the next. (Fig. 2). *Fragilaria construens* var. *venter* was also found in greatest concentration in bottom samples taken from the littoral zone. It was also similar to the var. *construens* in that the concentration of cells differed significantly between surface and bottom samples (P = 0.0385), between limnetic and littoral zones (P = 0.0153) and in surface and bottom samples from limnetic and littoral zones (P = 0.0391). The concentration of var. *venter* in the littoral-bottom samples in May and August is a trifle larger than that observed for the nominate variety, whereas in July it was distinctly lower (Table 2).

TABLE 1. Mean cell concentrations for *Fragilaria construens* var. *construens* in surface and bottom samples (all data expressed × 10^3 cells/1).

	Limnetic Zone	Littoral Zone
May		
Surface Samples	2.00	4.00
Bottom Samples	1.50	54.94
July		
Surface Samples	11.80	5.69
Bottom Samples	2.90	58.88
August		
Surface Samples	0.20	17.94
Bottom Samples	0.60	42.06

TABLE 2. Mean cell concentrations for *Fragilaria construens* var. *venter* in surface and bottom samples (all data expressed × 10^3 cells/1).

	Limnetic Zone	Littoral Zone
May		
Surface Samples	0.50	1.80
Bottom Samples	2.50	57.81
July		
Surface Samples	6.30	6.25
Bottom Samples	3.90	35.88
August		
Surface Samples	3.50	13.56
Bottom Samples	4.10	48.00

Fragilaria crotonensis Kitton

This species reached its greatest relative abundance in May and July (Fig. 1), when it was found in concentrations of 26.61 ± 9.69 × 10^3 cells/1 and 66.25 ± 9.69 × 10^3 cells/1, respectively. By August its concentration had diminished to 8.06 ± 9.69 × 10^3 cells/1. *Fragilaria crotonensis* was equally abundant in surface and bottom samples, in both limnetic and littoral zones during the entire sampling period. The extreme abundance of this plant in the littoral zone in July was puzzling to us since we had found that the numbers of *C. stelligera* had diminished in this same region considerably.

Fragilaria pinnata Ehr.

Fragilaria pinnata was detected in small numbers in May (Fig. 2), although in July and August its concentration had increased significantly (P = 0.0052). Further data analysis indicated that there was also a significant difference in the concentration of *F. pinnata* from surface and bottom samples within limnetic and littoral zones (P = 0.0542). *Fragilaria pinnata* was concentrated more in bottom samples taken from the littoral zone (see Table 3). It is similar in this respect to *F. construens* var. *construens* and *F. construens* var. *venter.* When compared to the latter two species, *F. pinnata* is present in littoral stations in about the same abundance; however, its concentration is higher in July and August in limnetic stations (compare Tables 1, 2, and 3).

The abundant occurrence of *F. construens* var. *construens, F. construens* var. *venter,* and *F. pinnata* in the littoral zone(s) of High Lake is most interesting. Although our sampling was restricted to the plankton diatom community, our data suggest that the above-mentioned taxa are probably originating either in the sediments of High Lake (from the benthic flora) and/or as epiphytes on selected macrophyte species. Through basic water movements (e.g., surface waves, seiches, underwater currents, etc.) these benthic and/or epiphytic cells become dislodged from their host substrates and become components of the phytoplankton community. To our knowledge, the three species of *Fragilaria* cited above have not been reported as members of an epiphytic diatom community; however, they have been reported repeatedly

TABLE 3. Mean cell concentrations for *Fragilaria pinnata* in surface and bottom samples (all data expressed X 10^3 cells/1).

	Limnetic Zone	Littoral Zone
May		
Surface Samples	0.00	0.00
Bottom Samples	0.10	0.00
July		
Surface Samples	14.90	10.69
Bottom Samples	5.40	52.94
August		
Surface Samples	6.20	27.69
Bottom Samples	6.80	44.81

in benthic communities by other investigators (Lund, 1972; Patrick & Reimer, 1966; Stoermer & Yang, 1970).

Stephanodiscus minutus Grun. *ex* Cl. & Moller

This species was significantly more abundant in August (P = 0.0475) than during May or July (Fig. 1). Its concentration at this time was 8.52 ± 1.14 X 10^3 cells/1. We also found that the concentration of *S. minutus* was significantly greater (P = 0.0670) in all surface samples (both limnetic and littoral) as opposed to bottom samples (i.e., 10.34 ± 1.62 X 10^3 cells/1 in surface samples opposed to 6.70 ± 1.62 X 10^3 cells/1 in bottom samples). Perhaps the same factors which caused reduction of *C. stelligera* in the littoral-bottom samples also apply to *S. minutus.*

SUMMARY

Asterionella formosa, Cyclotella stelligera, Fragilaria construens var. *construens, F. construens* var. *venter, F. crotonensis, F. pinnata,* and *Stephanodiscus minutus* are the major plankton diatoms in the High Lake flora. *Cyclotella stelligera* and *S. minutus* are more or less restricted to the limnetic zone of the lake, while *F. construens* var. *venter* and *F. pinnata* show a preference for the littoral zone(s). *Asterionella formosa* and *F. crotonensis* are not restricted to any one area.

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Peterson, Wilbur. 1977. Dicranum ontariense Peterson: A new name for a North American endemic moss. Canad. Jour. Bot. 55:986-991. [Distribution map for the moss previously known in North America as *D. drummondii* shows two Michigan localities, and a third (in Cheboygan Co.) is cited.]

Puff, C. 1976. The Galium trifidum group (Galium sect. Aparinoides, Rubiaceae). Canad. Jour. Bot. 54:1911-1925. [*G. tinctorium* ssp. *tinctorium, G. brevipes,* and *G. trifidum* ssp. *trifidum* all mapped with Michigan localities—but on a very small scale.]

Puff, Christian. 1977. The Galium obtusum group (Galium sect. Aparinoides, Rubiaceae). Bull. Torrey Bot. Club 104:202-208. [Small-scale distribution maps include occurrences of *G. labradoricum* and *G. obtusum* ssp. *obtusum* in Michigan.]

Reader, R. J. 1975. Effect of temperature on the flowering date of dogwood (Cornus florida). Canad. Jour. Bot. 53:1523-1534. [Maps include range in southern Michigan.]

Redhead, Scott A. 1977. The genus Mitrula in North America. Canad. Jour. Bot. 55:307-325. [Three of the four species in the genus, including two new ones, occur in North America including Michigan, for which specimens are mapped and cited, though with considerable garbling of geographic data (non-existent or erroneous counties, misspellings, etc.), some of which may result from unintelligible labels. In addition, *Verpatinia morchelloides,* transferred from *Mitrula,* is cited from Alger Co. (known only from type locality).]

Reznicek, A. A., & R. S. W. Bobette. 1976. The taxonomy of Potamogeton subsection Hybridi in North America. Rhodora 78:650-673. [Distribution maps include dots for Michigan occurrences of *P. spirillus* and *P. bicupulatus* (previously known as *P. capillaceus*).]

Richardson, Curtis J., & Charles W. Cares. 1976. An analysis of elm (Ulmus americana) mortality in a second-growth hardwood forest in southeastern Michigan. Canad. Jour. Bot. 54:1120-1125 + table. [Study site in Wayne Co.]

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Sparrow, F. K., & Lene Lange. 1977. Some bog chytrids. Canad. Jour. Bot. 55:1879-1890. [Twenty species from a bog on Johnson Rd., Maple River Tp., Emmet Co.—three of them new.]

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Vander Kloet, S. P. 1978. Systematics, distribution, and nomenclature of the polymorphic Vaccinium angustifolium. Rhodora 80:358-376. [Distribution map of the species (including *V. brittonii* & *V. lamarckii*) shows it essentially throughout Michigan; selected specimens cited include five Michigan counties, all in Lower Peninsula.]

Vander Kloet, S. P. 1978. The taxonomic status of Vaccinium pallidum, the hillside blueberries including Vaccinium vacillans. Canad. Jour. Bot. 56:1559-1574. [Representative specimens cited from four counties in the southern part of Mich.; some additional ones are included on distribution map.]

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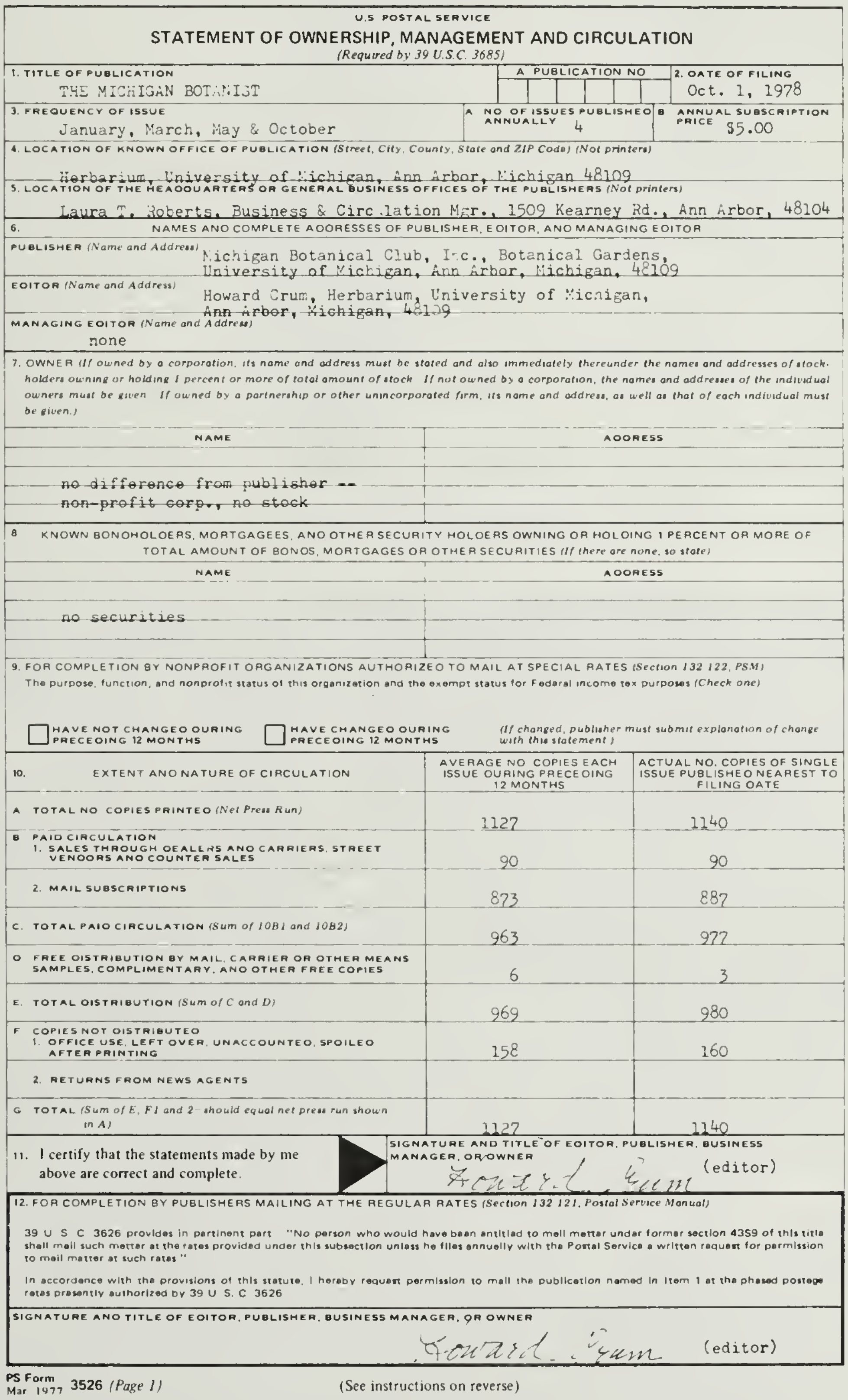
Widén, C.-J., D. M. Britton, W. H. Wagner, Jr., & F. S. Wagner. 1975. Chemotaxonomic studies on hybrids of Dryopteris in eastern North America. Canad. Jour. Bot. 53:1554-1567. [Many of the collections studied were from Michigan, the locations usually cited only to county.

Wilbur, Robert L. 1975. A revision of the North American genus Amorpha (Leguminosae-Psoraleae). Rhodora 77:337-409. [Distribution maps include Michigan occurrences of *A. canescens* and *A. fruticosa.*]



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CONTENTS

The Clubmosses Lycopodium sitchense and L. sabinifolium in the Upper Great Lakes Region
Joseph M. Beitel 3

Reviews 14, 24

Conidial Ultrastructure and Taxonomic Affinity of a Fungal Parasite of Sphagnum
Robert Chau 15

Announcements 18, 29, 43

Strobilus Variation in Clones of Running Pine, Lycopodium flabelliforme
W. H. Wagner, Jr., and Joseph M. Beitel 19

Some unusual Fissidens Collections from Michigan's Upper Peninsula
Janice M. Glime and Janet F. Gereau 25

Boletus sphaerocystis, a Little-Known Edible Bolete
Nancy S. Weber 27

Michigan Plants in Print 30, 36, 42

Observations on Houghton's Goldenrod (Solidago Houghtonii)
J. K. Morton 31

Investigations on the Freshwater Algae of Wisconsin. II
Louis L. Lipsey, Jr., and Mason G. Fenwick 37

On the cover: Michigan Botanical Club
Spring Outing, April 1978, at Camp Makasabe.
John Beaman demonstrating plant to R. E. Whiting
with (left to right) Dee LaBatt, Janet Strally, Richard
Pippen, and Paul Olexia (photo by Clayton Alway)

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THE

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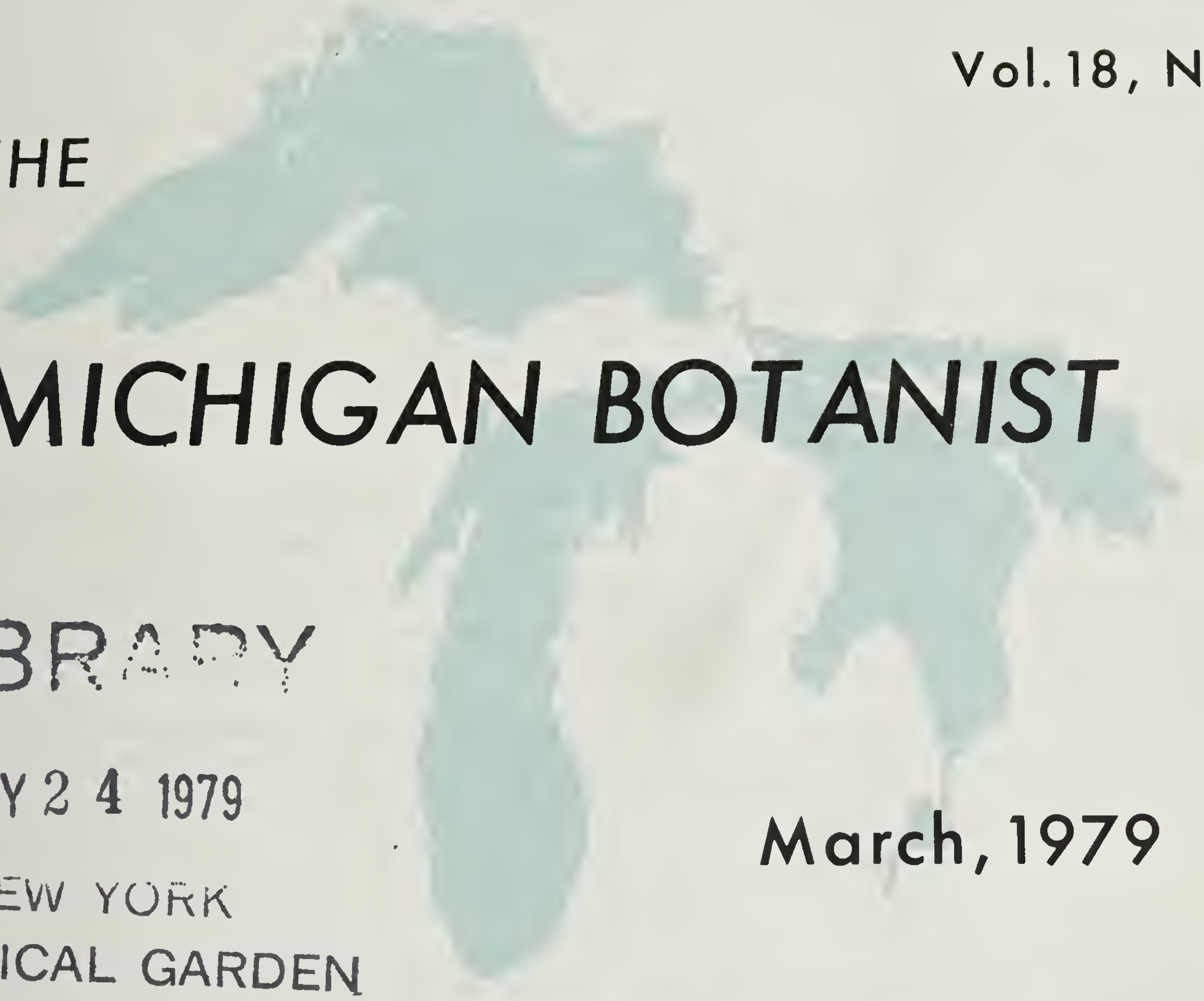

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THE COMPARATIVE ECOLOGY AND FREQUENCIES OF INTERSPECIFIC HYBRIDIZATION OF MICHIGAN WOODFERNS

Thomas J. Carlson

Dept. of Botany
University of Michigan
Ann Arbor, 48109

The Woodferns, which constitute the genus, *Dryopteris,* are one of the largest and most diverse genera of ferns in the Great Lakes region (Fig. 1) and are well known for engaging in extensive interspecific hybridization. One is likely to find hybrids wherever two or more species occur in proximity. Therefore, a comparative study of the habitats of the Woodfern species in the Great Lakes region should aid in understanding patterns of hybridization among these complex pteridophytes.

The Woodferns have been subjected to intensive taxonomic, cytological, and pharmacological studies during the past 20 years, in the United States (Wagner, 1971; Wagner & Hagenah, 1962; Wagner & Wag-

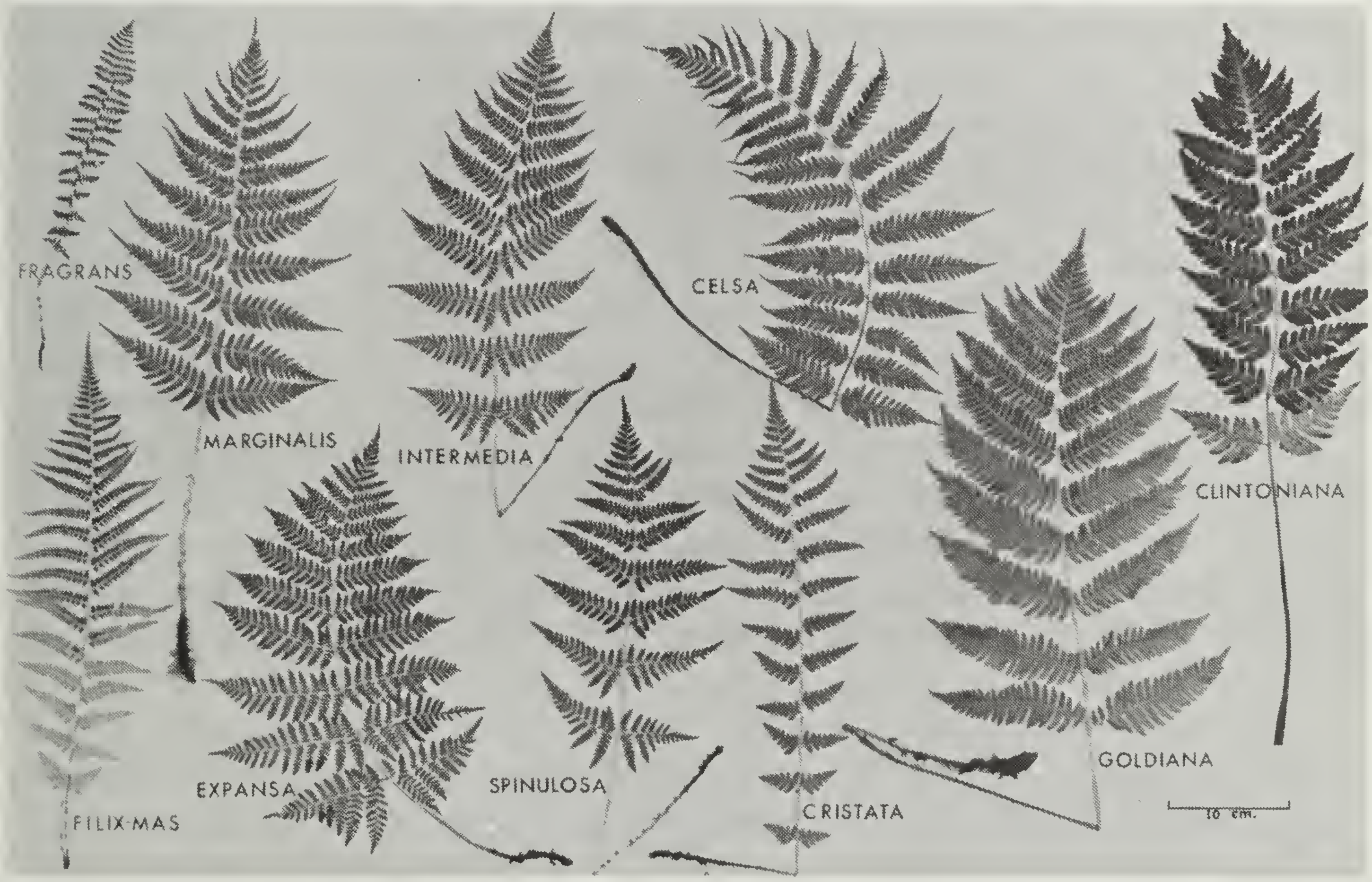


Fig. 1. The Dryopteris species of Michigan.—*D. fragrans,* Minn., St. Louis Co., Wagner 73277; *D. filix-mas,* Mich., Mackinac Co., Beitel 77274.5; *D. marginalis,* Mich., Emmet Co., Carlson 77019; *D. expansa,* Minn., Clearwater Co., Wagner 77407; *D. intermedia,* Mich., Emmet Co., Carlson 77018; *D. spinulosa,* Mich., Cheboygan Co., Carlson 77010; *D. celsa,* Mich., Cass Co., Carlson 74025; *D. cristata,* Mich., Cheboygan Co., Carlson 77011; *D. goldiana,* Mich., Cheboygan Co., Carlson 77021; *D. clintoniana,* Mich., Emmet Co., Carlson 77016.

ner, 1965) Canada (Britton & Soper, 1966; Britton & Widén, 1974; Britton et al., 1975), Japan (Hirabayashi, 1974), and Europe (Walker, 1959; Widén, 1972).

During the summer of 1977, I made extensive observations on Woodferns in Michigan and adjacent Canada, particularly in Emmet and Cheboygan counties at the northern tip of the Lower Peninsula of Michigan. In this report, I shall describe the habitats of the ten species occurring in Michigan and then provide a composite description of the habitats of the six species that occur in Emmet and Cheboygan counties so that their ecological relationships may be seen more clearly. Finally, I will show how this knowledge of the various species in relation to their habitats can lead to a greater understanding of their hybridization patterns.

Each species was studied at a minimum of 20 different sites. At each locality the following parameters were observed: associated herbs (including pteridophytes) within a 5-meter radius; associated woods plants within a 10-meter radius; texture, pH, and moisture content of the soil; degree of exposure; direction of slope; amount of disturbance; density of fern under consideration; and density of associated plants.

The most abundant Woodfern in Michigan, and the one with the widest spectrum of habitats, is the eastern North American endemic *Dryopteris intermedia* (L.) Gray, or Fancy Woodfern, which has finely-cut, bright, evergreen fronds. Its principal habitats are moist woods, where it is often the most common pteridophyte, and hummocks in swamps. It also occurs in dry woods, on shaded limestone and dolomite escarpments, and occasionally at bog margins and on hummocks in marshes and wet meadows. It prefers rich sub-acid to circumneutral soils.

The circumboreal *Dryopteris spinulosa* (Mueller) Watt, or Spinulose Woodfern, which has elongate triangular, pale-green, twice-pinnate, deciduous fronds is more prevalent on wetter and more acidic lowland soils and is considerably less common in forests than *D. intermedia*. The spinulose Woodfern is primarily a swamp plant, but it also grows in marshes and wet meadows and at bog margins. When *D. spinulosa* does occur in forests, it prefers richer, lower regions and wet crevices, but it is occasionally found in upland pine woods. It prefers rich, mostly sub-acid soils, but it may grow among acid *Sphagnum* moss. *D. spinulosa* and *D. intermedia* are usually associated with *Athyrium filix-femina* (Lady-fern), which is probably the most common pteridophyte associate of Michigan Woodferns.

Another circumboreal species, the Crested Woodfern, *Dryopteris cristata* (L.) Gray, which has stiffly erect and narrow, deciduous fertile fronds and short, partially evergreen sterile fronds, is nearly always confined to swamps, wet thickets, marshes, wet meadows and bog margins. Occasionally it may also be found in wet areas of woods, and rarely in pine woods or pine plantations. It grows mostly in sub-acid soils, but it also may grow among acid *Sphagnum* moss. It is less abundant in Michigan than either *D. intermedia* or *D. spinulosa*. Wherever *D. cristata* is found, *D. spinulosa* and the nearly ubiquitous *D. intermedia* will often be found nearby.

Another eastern North American endemic, the Marginal Woodfern, *Dryopteris marginalis* (L.) Gray, which is less common than *D. cristata,* is distinguished from the other Woodferns by its thick, almost rubbery, gray-green, rather dull, evergreen fronds. It usually occurs on relatively dry and often rocky north- or east-facing slopes in upland woods, and may also grow on dry, exposed or shaded rock ledges or clay banks. *D. marginalis* occasionally grows in swamps where it is usually restricted to the margins or the drier hummocks and tree stumps. Normally it is found in sterile, sub-acid or, less commonly, circumneutral soil. *D. marginalis* usually grows alone or with *D. intermedia,* but it occasionally associates with *D. spinulosa* and *D. cristata* when it extends into wet habitats.

Goldie's Woodfern, *Dryopteris goldiana* (Hooker) Gray, is also endemic to eastern North America and is the most striking Woodfern in Michigan because of its large size (up to 1.3 meters in height) and its coarse, bluish-green fronds which are deciduous. In Michigan it is most frequent in the southern counties, where it is local and uncommon. It is rare in the northern part of the Lower Peninsula and has been recorded only a few times in the Upper Peninsula. *D. goldiana* often exists in dense but very localized colonies. It develops mainly on seepage slopes or in the lower, moister areas of Beech-Sugar Maple-Basswood forests where rich, densely shaded vegetation and springy conditions produce humus-rich, black circumneutral soil. It sometimes also occurs on wet talus slopes or in swamps, where it is restricted to the margins or the drier hummocks. *Athyrium pycnocarpon* (Gladefern) and *Athyrium thelypterioides* (Silvery Glade fern) are often associated with *Dryopteris goldiana,* as are also *D. intermedia, D. spinulosa, Athyrium filix-femina,* and *Adiantum pedatum* (Maidenhair fern).

Clinton's Woodfern, *Dryopteris clintoniana* (Eaton) Underwood, which is endemic to eastern North America, has thick, partially evergreen blades and is most often found on swamp margins or hummocks, but it also is found in wet thickets and low wet woods. It grows in rich sub-acid soils and is commonly associated with *D. cristata, D. spinulosa,* and *D. intermedia.* Clinton's fern prefers somewhat moister soil than *D. goldiana* but slightly drier conditions than *D. cristata.*

Another eastern North American endemic, *Dryopteris celsa* (Palmer) Small, or Log fern, is a rare fern with firm, partially evergreen fronds. It occurs in Michigan in only a few southwestern counties and grows in moderately to strongly acid soils, on rotting logs and on humus-rich hummocks in shaded swamps. It occasionally occurs in rich seepage habitats like those of *D. goldiana,* and it is often associated with *Athyrium pycnocarpon* and *A. thelypterioides.* The Woodferns most commonly associated with the Log fern are *D. cristata, D. spinulosa,* and *D. intermedia.*

The Spreading Woodfern, *Dryopteris expansa* (C. Presl) Fraser-Jenkins & Jermy, known in much previous botanical literature as *Dryopteris dilatata* (Hoffm.) Gray or *Dryopteris assimilis* S. Walker, is a circumboreal species found in Michigan only in the Upper Peninsula. It has broad, finely divided, deciduous fronds that have exaggerated triangular basal pinnae. The lower basal pinnules of the basal pinnae are much elongated. It grows in cool, moist, rocky woods, on ravine slopes (particularly in the lower and north-facing regions of the ravines), and occasionally on swamp margins. It prefers cool, humus-rich, mostly sub-acid soils.

The Male fern, *Dryopteris filix-mas* (L.) Schott, another circumboreal species, has slender pinnae and short stipes that are densely covered with brown scales. Its fronds are thick-textured, but deciduous. Its greatest abundance in Michigan is in the western part of the Upper Peninsula, where it occurs uncommonly. The Male fern may live in woodlands and on shaded talus slopes, usually of limestone or calcareous shale, and on circumneutral soil. It occasionally grows in limesinks, such as those near Leer, Alpena Co., Michigan, which are the only recorded localities for the Male fern in the Lower Peninsula. *D. filix-mas* also grows in small cracks and crevices of exposed limestone pavements and boulders, like those northwest of St. Ignace, Mackinac Co., Michigan, or on shaded or exposed neutral basaltic rocks, as in the Porcupine Mountains in Ontonagon Co., Michigan. In dry upland areas, particularly on boulders, it is sometimes associated with *Polystichum lonchitis* (Northern Holly fern), *Asplenium viride* (Green Spleenwort), and occasionally *Dryopteris marginalis.*

Another circumboreal species, the Fragrant fern, *Dryopteris fragrans* (L.) Schott, is the smallest of the North American Woodferns. The undersides of its small, thick, deciduous fronds have many fragrantly aromatic glandular hairs, and its rootstocks usually retain a conspicuous mat of brown withering fronds. In Michigan it is found mainly in the western part of the upper Peninsula, where it is uncommon. The Fragrant fern grows in sub-acid to circumneutral soils on rocks and on shaded or exposed and usually north-facing vertical cliffs. On dry rocks near *D. fragrans* may grow *Selaginella rupestris* (Rock Spike-moss), *Woodsia ilvensis* (Rusty Cliff fern), *Polypodium virginianum* (Rock-cap fern), and rarely *Dryopteris marginalis.* A well-known locality for the Fragrant fern is the escarpment overlooking Lake of the Clouds in the Porcupine Mountains.

Habitats of Woodferns in Emmet and Cheboygan Counties

The six species of Woodferns which occur in Emmet and Cheboygan counties are, in decreasing order of abundance, *Dryopteris intermedia, D. spinulosa, D. cristata, D. marginalis, D. goldiana,* and *D. clintoniana.* I studied these six species in detail at several localities in these two counties in order to determine the optimal habitat for each and the ecological relationships between them.

A generalized sequence of Woodfern species following a gradient from dry, upland forest communities down through more mesic forests, swamps, wet meadows, marshes or bogs to open water is summarized in

Figure 2. Although there are exceptions to the scheme presented here, it is, nevertheless, a good approximation of what is usually found in nature.

The dry upland forest (to the left on Fig. 2) represents stands of pine or mixed stands of pine, poplar, and oak. Exposed openings in these forests may be common. One or more of the following species, *Pinus sylvestris* (Scots Pine), *P. resinosa* (Red Pine), and *P. strobus* (White Pine), may be present. The mixed stands of pine, poplar, and oak consist mainly of combinations of those pines, *Populus tremuloides* (Trembling Aspen), *Populus grandidentata* (Big-toothed Aspen), *Betula papyrifera* (Paper Birch), and *Quercus rubra* (Red Oak). These upland forests grade downward into mixed stands of *Fagus grandifolia* (American Beech), *Acer saccharum* (Sugar Maple), *Tilia americana* (American Basswood), and *Fraxinus americana* (White Ash). *Quercus rubra* and *Pinus strobus* may also grow in these mesic forests. The lower areas of these mesic forests are represented as rich seepage habitats which grade into white cedar swamps or mixed cedar-hardwood swamps, which in turn often border wet meadows, marshes, bogs, or open water. The dominant tree in the cedar swamps is *Thuja occidentalis* (Eastern White Cedar). The

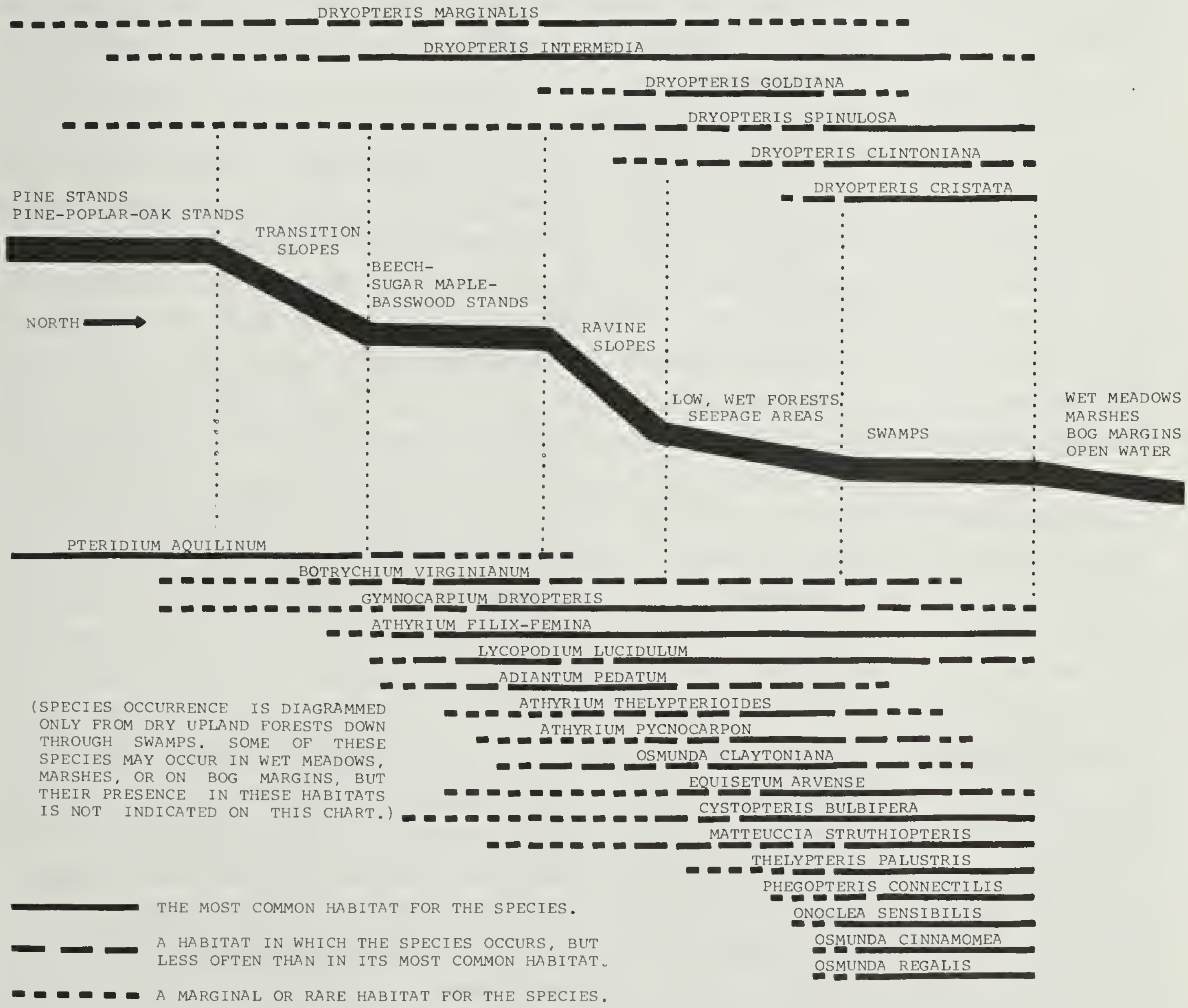


Fig. 2. Generalized transect from dry upland forests down through swamps, showing the habitats of the Woodferns and their common pteridophyte associates in Emmet and Cheboygan Counties.

mixed cedar-hardwood swamps consist predominantly of *Thuja, Acer rubrum* (Red Maple), *Fraxinus nigra* (Black Ash), *Abies balsamea* (Balsam Fir), *Betula alleghaniensis* (Yellow Birch), *Tsuga canadensis* (Hemlock), and living and dead trees of *Ulmus americana* (American Elm).

In the driest, most open upland forests, *Pteridium aquilinum* (Bracken fern) is usually the dominant fern. Club-mosses from the *Lycopodium complanatum* complex and various species of *Botrychium* (Grapeferns) may also grow in these areas, but few or no Woodferns are found. In the more moist and less open upland forests, *Dryopteris marginalis* is occasional, while *D. intermedia* and *D. spinulosa* occur only uncommonly. In the drier regions of the Beech-Sugar Maple-Basswood forests *Pteridium aquilinum* becomes less common, and *Dryopteris intermedia* is often the only Woodfern present, although *D. marginalis* may be found, particularly on the sides of steep, north-facing talus slopes. *D. intermedia* is often the most common pteridophyte in Beech-Sugar Maple-Basswood forests, and *Athyrium filix-femina* is also common. *Gymnocarpium dryopteris* (Oak fern), *Botrychium virginianum* (Rattlesnake fern), and several species of *Lycopodium* (Club-mosses) may also be associated with *Dryopteris intermedia* in these forests. In the moister areas of the forests *D. spinulosa* is often present though usually less abundant than *D. intermedia.*

Many Beech-Sugar Maple-Basswood forests, particularly those bordering lakes or rivers, have long, sloped ravines that extend from the upper regions of the forest and eventually fan out into swamps. On the north-facing slopes of these ravines *Dryopteris marginalis* and *D. intermedia* are usually present. At the bases of these slopes, the ground gets much moister, and the abundance of *D. intermedia* increases while that of *D. marginalis* decreases. On the floors of these ravines, *D. intermedia, D. spinulosa,* and *Athyrium filix-femina* are all quite abundant while only scattered plants of *Dryopteris marginalis* are present and a few plants of Michigan's largest Woodfern, *D. goldiana* begin to appear. In their lower regions, the ravine floors widen and get wetter and richer from seepage and from higher water tables. Here, *D. goldiana* may grow in dense clumps. Common pteridophyte associates of *D. goldiana* are *Athyrium pycnocarpon, Athyrium thelypterioides, Adiantum pedatum, Dryopteris intermedia, D. spinulosa,* and *Athyrium filix-femina.* As the ravines fan out into swamps, the soil becomes wetter, *Dryopteris spinulosa* becomes more abundant, and *D. intermedia* and *D. goldiana* become less abundant. Scattered plants of *D. clintoniana* and *D. marginalis* may be found in the low seepage areas, on the swamp margins and on hummocks in swamps. *D. intermedia* prefers the hummocks, but *D. spinulosa* and *D. cristata* are not as selective, for they also thrive in the wetter areas. *Thelypteris palustris* (Marsh fern), *Cystopteris bulbifera* (Bulblet fern), *Athyrium filix-femina,* and *Gymnocarpium dryopteris* are common swamp associates of Woodferns. In the wettest and richest areas of the swamp, where only scattered plants of *Dryopteris spinulosa* and *D. cristata* are normally present, *Osmunda cinnamomea* (Cinnamon fern), *Osmunda regalis* (Royal fern), *Onoclea sensibilis* (Sensitive fern), *Phegopteris connectilis* (Northern Beech fern), *Matteuccia struthiopteris* (Ostrich fern), *Athyrium filix-femina, Cystopteris bulbifera,* and *Thelypteris palustris* may be present in dense clumps.

Of the six Woodferns in Emmet and Cheboygan counties, the one least restricted to shaded, moist or wet conditions is *Dryopteris marginalis,* for it may occasionally be found, as noted above, in dry areas exposed to direct sunlight. The other Woodfern species are, for the most part, restricted to shaded, moist, or wet conditions in woods and swamps, although *D. cristata, D. spinulosa,* and *D. intermedia* may grow in marshes and wet meadows, and on bog margins. In Emmet and Cheboygan counties, *D. intermedia* and *D. spinulosa* are abundant, and *D. cristata* is common, while *D. marginalis* is uncommon, and *D. goldiana* and *D. clintoniana* are rare, for they are often absent from habitats where they would be expected to occur.

The Woodfern abundances indicated above are those I observed in Emmet and Cheboygan counties. The relative numbers of some of the species differ in other parts of the Great Lakes Region. Northward into the Upper Peninsula and Canada the climate becomes colder and the terrain hillier and rockier with increased exposure of bedrock. *Dryopteris fragrans, D. filix-mas,* and *D. expansa,* which are absent in Emmet and Cheboygan counties, are present, while *D. goldiana, D. marginalis,* and *D. clintoniana* decrease in abundance and eventually disappear. The frequencies of *D. intermedia, D. spinulosa,* and *D. cristata* remain about the same. Southward through the Lower Peninsula, toward a warmer climate and flatter terrain, the incidence of bogs and swamps decreases, and the Woodferns are generally less common. Bedrock outcrops are rare, and consequently the species that grow on them, *D. fragrans* and *D. filix-mas,* are absent, as is *D. expansa* which prefers the colder climate. *D. intermedia* is less common, while *D. spinulosa* and *D. cristata* again show no appreciable change in abundance. *D. marginalis* is slightly less common, except in the forests on the sand dunes near Lake Michigan, where it is common on the north-facing slopes. *D. goldiana* and *D. clintoniana* become more abundant, while *D. celsa* makes its only Michigan appearance in a few southwestern counties. All three of these species are uncommon or rare.

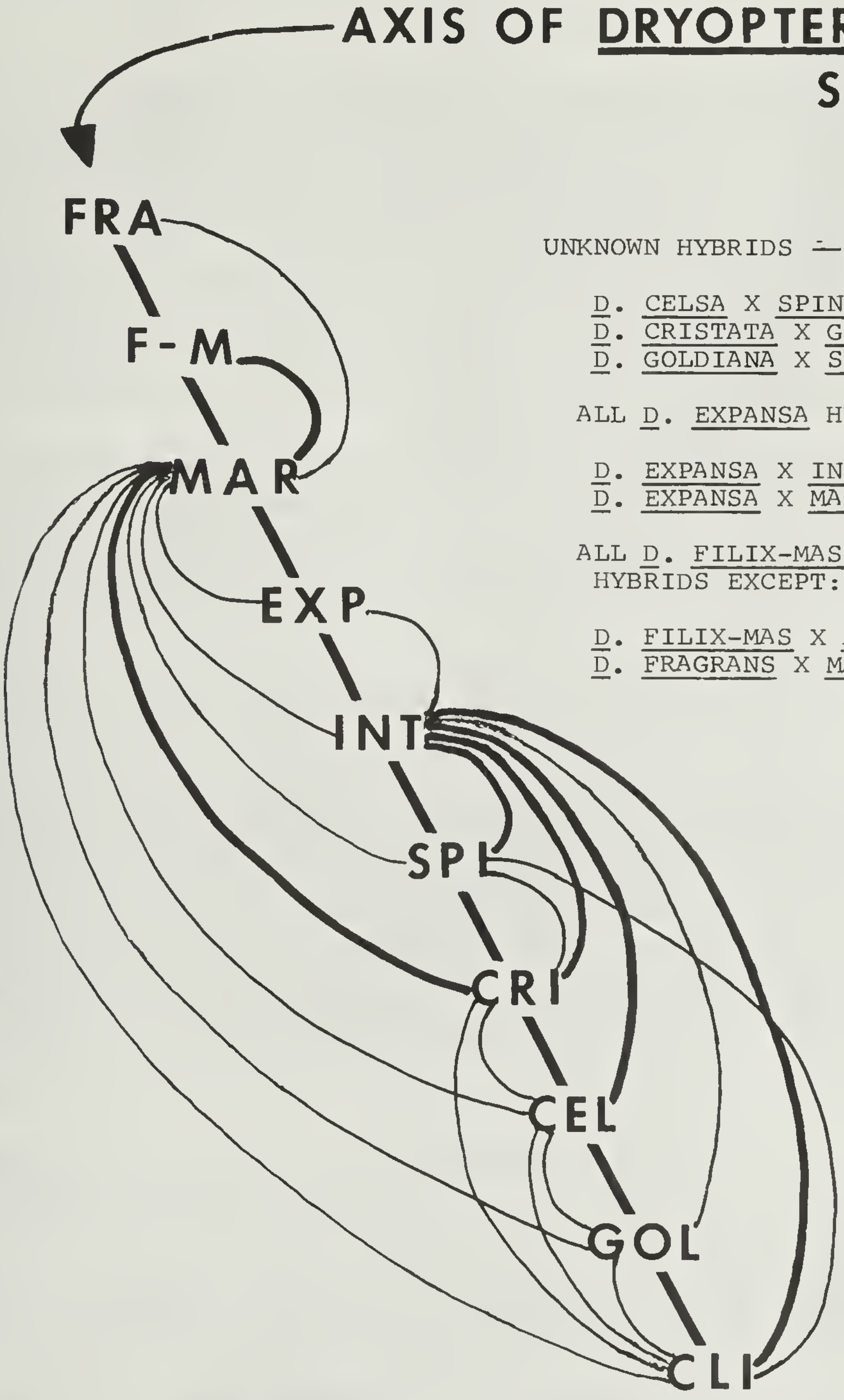
Hybridization

With a few exceptions, the presence of two or more woodfern species in proximity is the only prerequisite for hybridization. Artificial disturbances, such as logging operations, fire, house or road construction, or the raising or lowering of water levels, result in open, disturbed ground which is very desirable for gametophyte establishment. Many *Dryopteris* hybrids are often found in these areas, but my observations indicate that artificial disturbance is not necessary for Woodfern hybridization. The places where ferns grow, however, are often naturally disturbed. Their sexual reproduction often occurs on old fallen logs, in swamps that are subject to periodic flooding, and in moist rock crevices, all of which are transient microhabitats. Naturally disturbed habitats have existed in the past even in the most primitive swamps and forests, and thus we have reason to believe that the formation of natural hybrids now is very similar to what it was in the past, wherever and whenever two or more species exist in the same or nearby habitats (Wagner & Hagenah, 1962). Disturbance by man is not necessary for hybridization, although it may increase its incidence by creating a more suitable juxtaposition of gametophytes.

Two or three species of Woodferns are commonly found in proximity and, rarely, as many as six species may be found near each other if the habitats are sufficiently varied. With few exceptions, all *Dryopteris* hybrids are sterile and are found near both parents. The hybrids usually occur as single plants, but they may occasionally grow in groups of several plants or rarely in colonies of dozens of plants. *D.* × *triploidea* Wherry *(D. intermedia* × *spinulosa)* and *D.* × *boottii* (Tuckerm.) Underw. *(D. cristata* × *intermedia)* are the most common Woodfern hybrids in Michigan. This is not surprising since their parents occur together so often.

Dryopteris fragrans and *D. filix-mas* are similar in that their main habitats are much different from those of the rest of the Woodferns. However, *D. marginalis* occasionally grows with *D. filix-mas* and rarely with *D. fragrans;* and in North America the two latter species are known to hybridize only with *D. marginalis*. The hybrid *D.* × *algonquinensis* D. M. Britton *(D. fragrans* × *marginalis)* is very rare and was found in Algonquin Park, Ontario, Canada (Britton *et al.,* 1975). The hybrid *D. filix-mas* × *marginalis* occurs sporadically but is usually common where it does occur. It is found on West Huron Island, Marquette Co., Michigan (Wagner & Hagenah, 1962) as well as in the limesinks near Leer, Alpena Co., Michigan.

The other Michigan Woodferns are more frequently associated with one another and thus permit more extensive hybridization. Figure 3 illustrates that, with few exceptions, hybridization is most common between the species whose habitats overlap most frequently. When a possible hybrid combination is not known to exist, it is usually implied that the most common habitats of the parents do not normally overlap. For some unknown reason, perhaps a genetic, physical, and/or ecological barrier, however, certain hybrids, particularly some of those involving *Dryopteris spinulosa* or *D. marginalis,* are rarer than would be expected from the frequencies with which their parents are associated. For example, the most common Woodfern associate of *D. marginalis* is *D. intermedia,* but the hybrid between them is much rarer than the hybrid between *D. marginalis* and *D. cristata* (*D.* × *slossonae* Wherry), which is a common Woodfern hybrid, even though *D. marginalis* grows with *D. cristata* much less frequently than it does with *D. intermedia*. The only common *D. spinulosa* hybrid is *D.* × *triploidea (D. intermedia* × *spinulosa)*. The rest of the possible hybrids involving *D. spinulosa* are uncommon to rare or unknown, even though the parents of some of the possible hybrids often grow together. For instance, *D. spinulosa* often grows with *D. clintoniana* and *D. celsa,* wherever either of the latter is found in Michi-



UNKNOWN HYBRIDS :–

D. CELSA X SPINULOSA
D. CRISTATA X GOLDIANA
D. GOLDIANA X SPINULOSA

ALL D. EXPANSA HYBRIDS EXCEPT:

D. EXPANSA X INTERMEDIA
D. EXPANSA X MARGINALIS

ALL D. FILIX-MAS AND D. FRAGRANS HYBRIDS EXCEPT:

D. FILIX-MAS X MARGINALIS
D. FRAGRANS X MARGINALIS

THE THICK LINE (▬) CONNECTING TWO SPECIES INDICATES THAT THE HYBRID COMBINATION OCCURS NEARLY EVERYWHERE THAT BOTH PARENTS OCCUR TOGETHER.

THE THIN LINE (—) CONNECTING TWO SPECIES INDICATES THAT THE HYBRID COMBINATION OCCURS MUCH LESS FREQUENTLY THAN THE CO-EXISTENCE OF THE PARENTS.

Fig. 3. Known hybrids among the Woodfern species of Michigan, occurring in the state or elsewhere (adapted from Wagner, 1971).

gan, but *D.* × *benedictii* Wherry *(D. clintoniana* × *spinulosa)* is quite rare, and the hybrid *D. celsa* × *spinulosa* is unknown (a plant presumed to be this hybrid—in Wagner & Wagner 1965—has not been verified cytogenetically). Another interesting example is *D.* × *uliginosa* Druce *(D. cristata* × *spinulosa),* which is much less common than *D.* × *boottii (D. cristata* × *intermedia)* even though the parents of each of these combinations are associated almost equally often.

SUMMARY

The habitats of the 10 species of Woodferns that grow in Michigan are wet meadows, marshes, bog margins [*D. cristata, D. spinulosa, D. intermedia* (on hummocks)]: swamps, swamp margins, wet thickets, low wet woods [*D. cristata, D. spinulosa, D. filix-mas* (limesinks). *D. intermedia, D. celsa, D. clintoniana, D. marginalis, D. goldiana*]; high, moist, beech-sugar maple-basswood forests (*D. intermedia, D. marginalis, D. goldiana, D. expansa, D. spinulosa, D. filix-mas*); shaded upland ravine slopes (*D. marginalis, D. intermedia, D. expansa*); dry upland pine or pine-poplar-oak forests (*D. marginalis, D. spinulosa, D. intermedia*); and rock cliffs (*D. fragrans, D. filix-mas, D. marginalis, D. intermedia*).

Usually the frequency of interspecific hybridization among the Woodferns is directly proportional to the frequencies in which their parents are associated, but there are exceptions. Perhaps because of a genetic, mechanical, and/or ecological barrier, certain hybrids are rarer than would be expected from the frequencies with which their parents occur together.

I wish to thank Dr. W. H. Wagner, Jr., who coordinated this study, supplied me with the proper resources, and critically reviewed the manuscript, and also Dr. E. G. Voss, who provided me with laboratory space and gave me precise directions to a number of localities which I studied while attending the University of Michigan Biological Station during the summer of 1977. I would also like to thank Michael J. Huft and A. A. Reznicek for reviewing the manuscript and giving several helpful suggestions and David J. Bay, Joseph M. Beitel, Michael Price, Florence S. Wagner, and Kerry S. Walter for their help in various ways. Voucher specimens are lodged in the University of Michigan Biological Station herbarium.

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THE GENUS PLACIDIOPSIS BELTR. (LICHENIZED ASCOMYCETES) NEW TO NORTH AMERICA AS PLACIDIOPSIS MINOR SP. NOV.

Richard C. Harris

University Herbarium
University of Michigan
Ann Arbor, 48109

Placidiopsis, a genus of the Verrucariaceae, is related to the more widely known genus *Dermatocarpon* but distinguished from it in having septate rather than simple spores. The thallus consists of small squamules broadly attached to the substrate, the ascocarp is a perithecium, paraphyses are lacking (or soon disappear if present in early stages of development), and the spores are 2-4-celled. About 20 species are currently included in the genus. Most of them occur in Europe, but two extra-European species have been described from New Zealand and Argentina. The genus is poorly known with most species represented by only one or at most a few specimens and is badly in need of revision. *Placidiopsis* has not been reported from North America previously.

Placidiopsis minor sp. nov.

Thallo minore, 0.25-0.75 mm diam., et sporis minoribus, 8-10 × 4-5 μm, a congeneribus differt.

Holotype: Virginia, Highland County, farm c. 9 mi S of Monterey on U.S. Hwy. 220, on non-calcareous pebbles exposed at top of clay bank, 9.VII.1975, *Harris 9964A* (MICH).

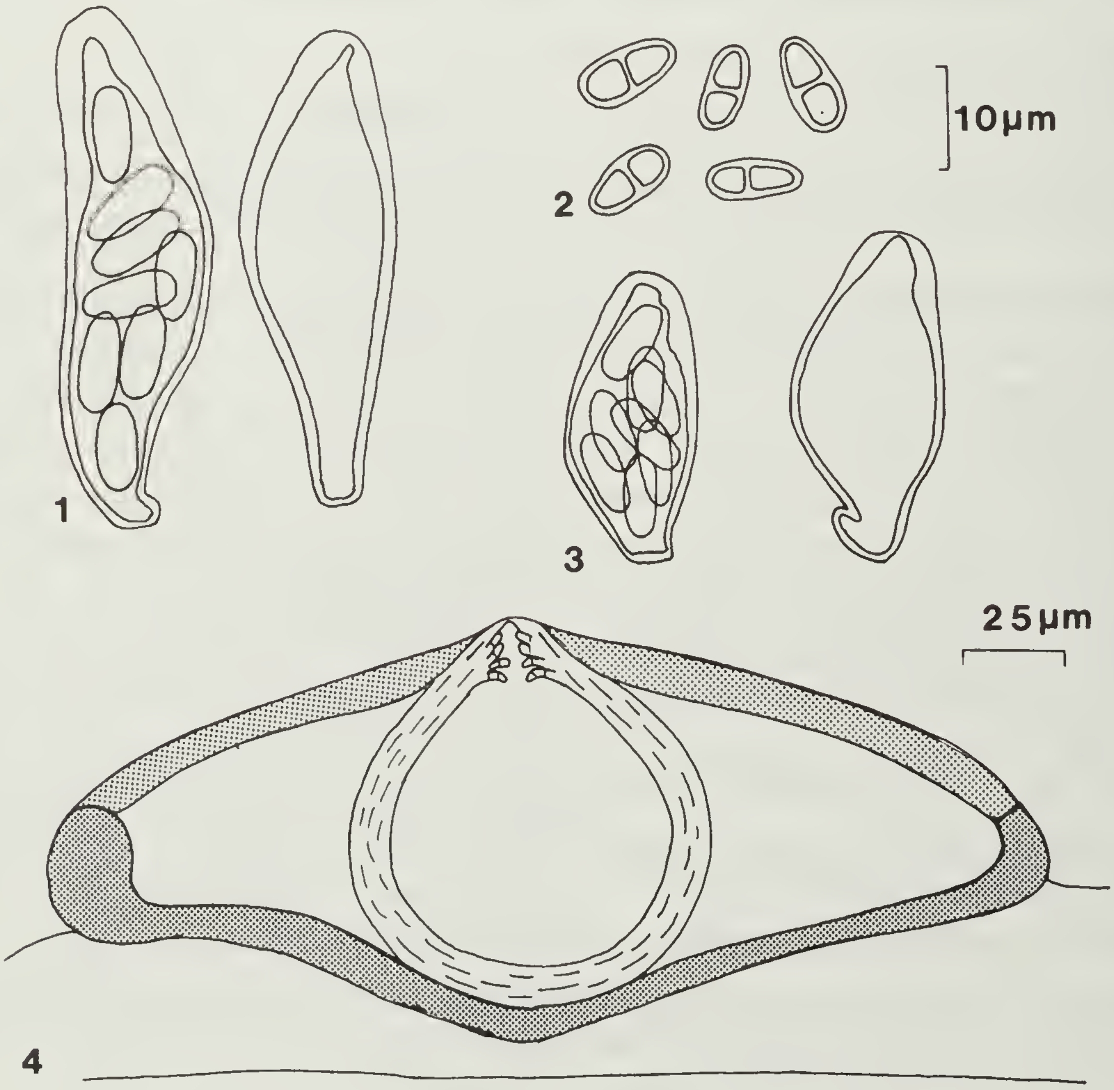
Thallus of minute, gray, areole-like squamules broadly attached to the substrate, 0.25-0.75 mm across, often with a narrow black rim. Squamules more or less rounded or quite irregular in shape due to crowding by adjacent thalli. Upper cortex paraplectenchymatous, essentially colorless but with fine, brownish granules obscuring the upper third. Lower cortex paraplectenchymatous, dark brown. Medulla with closely packed green algae obscuring the medullary hyphae.

Tips of perithecia evident as small black dots, one to many in a squamule. Perithecia up to 100 μm across. Perithecial wall thin, c. 5 μm, consisting of parallel hyphae with somewhat elongate cells, c. 5 × 1 μm, colorless except near ostiole. Periphyses present, short, consisting of one to few cells. Paraphyses absent. Asci rather variable, obclavate, ellipsoidal to nearly clavate, 30-50 × 12-15 μm. Spores 8/ascus, irregularly arranged, 2-celled with upper cell shorter, 8-10 × 4-5 μm.

Additional specimen seen. Michigan, Livingston County, Brighton Recreation Area, NW corner of Hamburg and Bishop Lake Roads, on a noncalcareous pebble among sparse grasses and herbs, 16.VII.1978, *Harris 13013* (MICH).

At first glance *Placidiopsis minor* resembles a small sterile *Acarospora.* However, a cross-section quickly reveals its true affinities. The species is clearly distinguished from all others of the genus by the small size of its thallus and spores. It is also distinctive in growing on rock rather than on soil, although the Michigan collection is only partly on rock and partly on the thallus of a sterile sorediate *Trapelia*.

Both collections come from habitats disturbed by erosion. This habitat is one of the more interesting for lichens in southern Michigan where due to the dryness of the air in summer the lichen flora is less rich than in areas with higher year-round humidity. On many clay or sand hillsides the grass and herb cover is sparse and localized erosion exposes large numbers of small pebbles which due to their proximity to the soil surface maintain sufficient humidity to support a considerable crustose lichen flora. In fact, in more extreme cases the lichens are confined to the margins of the pebbles. Undoubtedly many more minute lichens such as *Placidiopsis* will be found in this microhabitat. Associated with both the type from Virginia and the Michigan specimen were *Lecidea erratica* Körb. and *Trapelia involuta* (Tayl.) Hert. A number of species were collected on nearby pebbles at the Michigan locality: *Acarospora immersa* Fink *in* Hedr., *A. oligospora* (Nyl.) Arn., *Acarospora* sp., *Endocarpon pusillum* Hedw., *Trapelia* sp., *Verrucaria muralis* Ach. and *Verrucaria* spp. This sort of habitat is common in Michigan and eastern North America and *Placidiopsis minor* may prove common but ignored due to its small size.



Figures 1-4. *Placidiopsis minor* sp. nov. 1. Asci. 2. Spores. 3. Asci. 4. Cross-section of a small thallus (schematic). (1-2 holotype; 3-4 Michigan, *Harris 13013*).

VEGETATION SUCCESSION IN SMITH'S BOG, CHEBOYGAN COUNTY, MICHIGAN[1]

Robert Sanger
1105 Tamarack Lane
Pittsburgh, Penn., 15237

and

John E. Gannon
State University Research Center
Oswego, N.Y., 13126

The purpose of this study was to assess changes in vegetation in Smith's Bog, Cheboygan County, Michigan (T37N, R3W, Sec. 35) over a period of some 60 years and to prepare a detailed vegetation map to serve as a basis for future comparison. Several approaches may be used in the study of wetland vegetation succession. The most efficient method for our purpose was to compare previous vegetation descriptions and maps with present conditions.

Data on species composition and distribution in Smith's Bog had been obtained intermittently since 1911 by various investigators at the University of Michigan Biological Station (Woollett et al., 1925; Gates, 1942; Johns, 1966). Although six decades is a comparatively short period in the hydrarch successional process, numerous small but significant vegetation changes have occurred.

Smith's Bog is a small, 3.1 ha (7.6-acre) wetland (Fig. 1). It has no surface inlet. The only outlet, a streamlet flowing south to a swamp forest, functions only during periods of high water levels. The wetland is surrounded by sandy upland soils forested predominantly with second growth aspen except for a lowland forest (mainly of dead elms) at its southernmost end. The wetland consists primarily of a well-grounded mat of sedges and shrubs with a shallow (< 1 m deep) open-water pool that narrows into a channel. The open-water zone is maintained by a slight current caused by groundwater seepage.

In 1911, Smith's Bog was considered to be a boreal "bog," typical of many other such wetland habitats in northern Michigan (Gates, 1942). Open water, occupying about two-fifths of the basin, was surrounded by a well-developed floating mat of *Carex lasiocarpa*. The mat was bordered by a *Chamaedaphne-Sphagnum* association, followed by high bog shrubs and "bog" trees, primarily *Picea mariana* and *Thuja occidentalis*. Fires, especially in 1914 and 1916, destroyed the trees and shrubs and part of the

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[1] This investigation was partially supported by a grant from the National Science Foundation's RANN program (AEN72-03483). It represents a contribution from the University of Michigan Biological Station and the State University Research Center at Oswego.

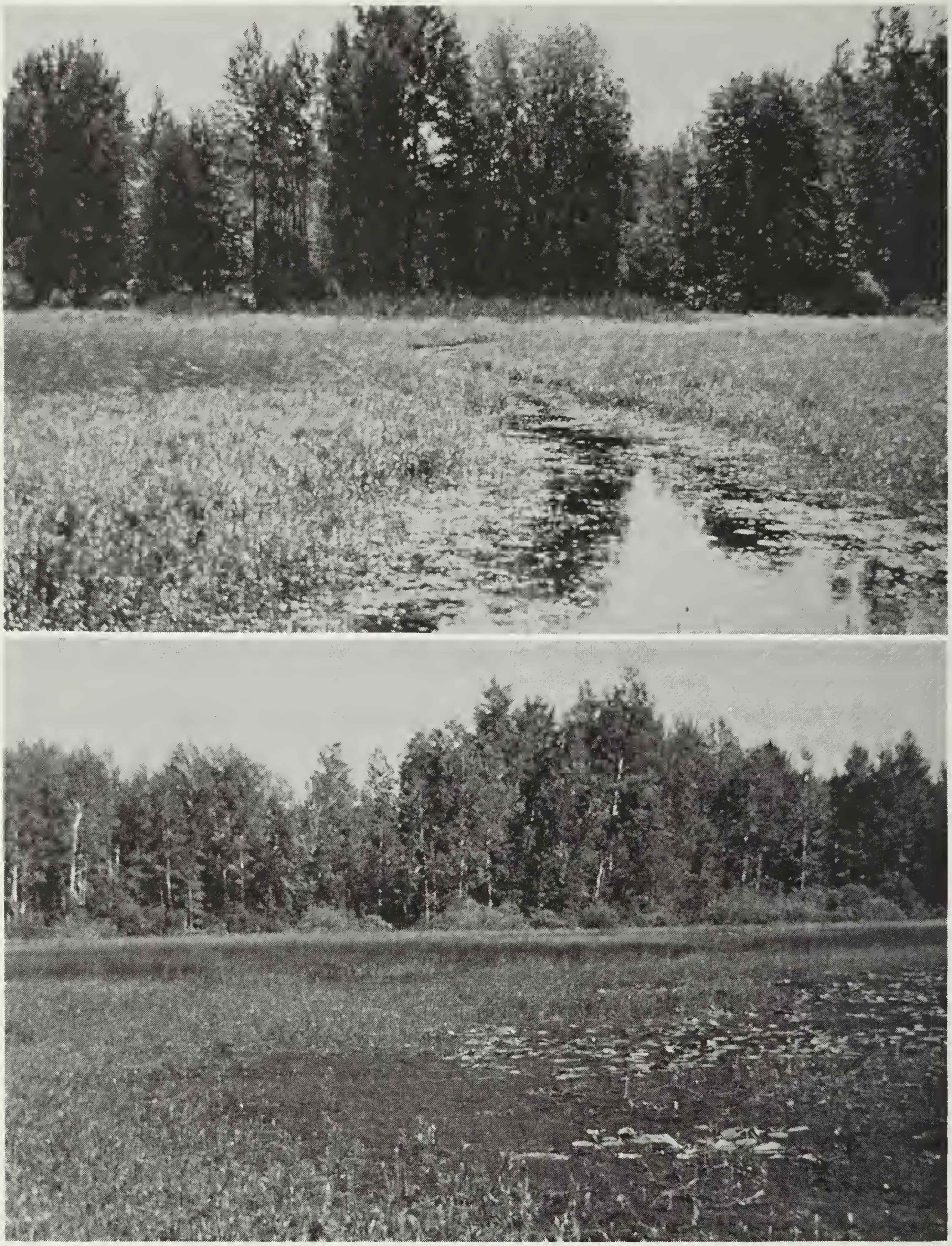

Fig. 1. Two views of Smith's Bog that illustrate significant changes in water level. *Top:* August, 1975, a high-water year. The sedge, *Dulichium arundinaceum,* is predominant near the open-water pool and channel. Photo by Robert Sanger. *Bottom:* August, 1977, a low-water year. The wetland became dry by late summer. Yellow waterlilies, *Nuphar variegatum,* lie on the mud bottom of the pool. Photo by Christa Schwintzer.

floating *Carex* mat became grounded. A greater portion of the mat became grounded by 1921 (Gates, 1942).

Further grounding of the *Carex lasiocarpa* mat was evident in 1924.

The species was strikingly predominant, and gave the bog the appearance of a grassy meadow. *Nuphar variegatum* occurred in the open-water, and *Dulichium arundinaceum* was scattered among *Carex* on the mat. *Salix* spp. were present, especially in the northern portion of the basin (Fig. 2). The few scattered clumps of *Chamaedaphne calyculata* which survived the fire did not appear to have increased in number. Woollett et al. (1925) predicted that the bog would become a dry *Carex* meadow in 10 to 20 years.

The *Carex lasiocarpa* mat remained grounded during the 1930's. This allowed for rapid growth of *Salix* spp. and the establishment of *Dulichium arundinaceum* along the margin of the open-water pool. *Typha latifolia,* once plentiful in the southern portion of the bog, became scarce following abandonment of an adjacent farm. Gates (1942) thought that the predomi-

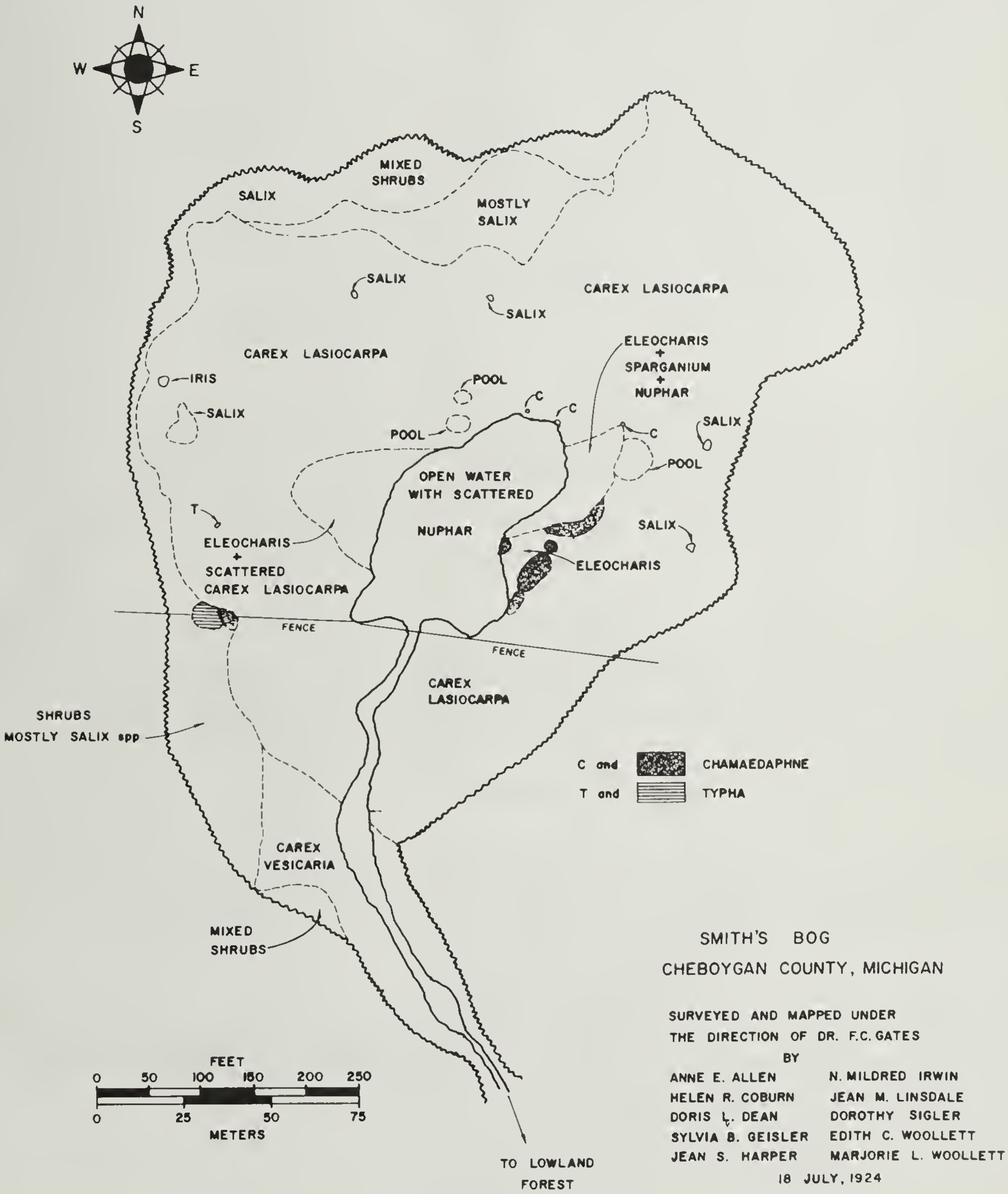
N
W
E
S
MIXED SHRUBS
SALIX
MOSTLY SALIX
SALIX
SALIX
CAREX LASIOCARPA
CAREX LASIOCARPA
ELEOCHARIS + SPARGANIUM + NUPHAR
IRIS
SALIX
POOL
C
C
POOL
C
SALIX
POOL
OPEN WATER WITH SCATTERED NUPHAR
T
SALIX
ELEOCHARIS + SCATTERED CAREX LASIOCARPA
ELEOCHARIS
FENCE
FENCE
CAREX LASIOCARPA
SHRUBS MOSTLY SALIX spp
C and ▨ CHAMAEDAPHNE
T and ▤ TYPHA
CAREX VESICARIA
MIXED SHRUBS
SMITH'S BOG
CHEBOYGAN COUNTY, MICHIGAN
SURVEYED AND MAPPED UNDER THE DIRECTION OF DR. F.C. GATES BY
ANNE E. ALLEN
HELEN R. COBURN
DORIS L. DEAN
SYLVIA B. GEISLER
JEAN S. HARPER
N. MILDRED IRWIN
JEAN M. LINSDALE
DOROTHY SIGLER
EDITH C. WOOLLETT
MARJORIE L. WOOLLETT
18 JULY, 1924
FEET
0 50 100 150 200 250
0 25 50 75
METERS
TO LOWLAND FOREST

Fig. 2. Predominant vegetation of Smith's Bog, 1924 (Redrawn from Woollett et al., 1925).

nant *Carex lasiocarpa* association would not continue to exist for more than 20 years.

By 1957, *Dulichium arundinaceum* occupied most of the former open-water pool (Fig. 3). *Eleocharis smallii (= palustris), Sparganium minimum,* and *Typha latifolia* were also found in this zone. The pool contained *Glyceria borealis,* as well as scattered individuals of *Nuphar*

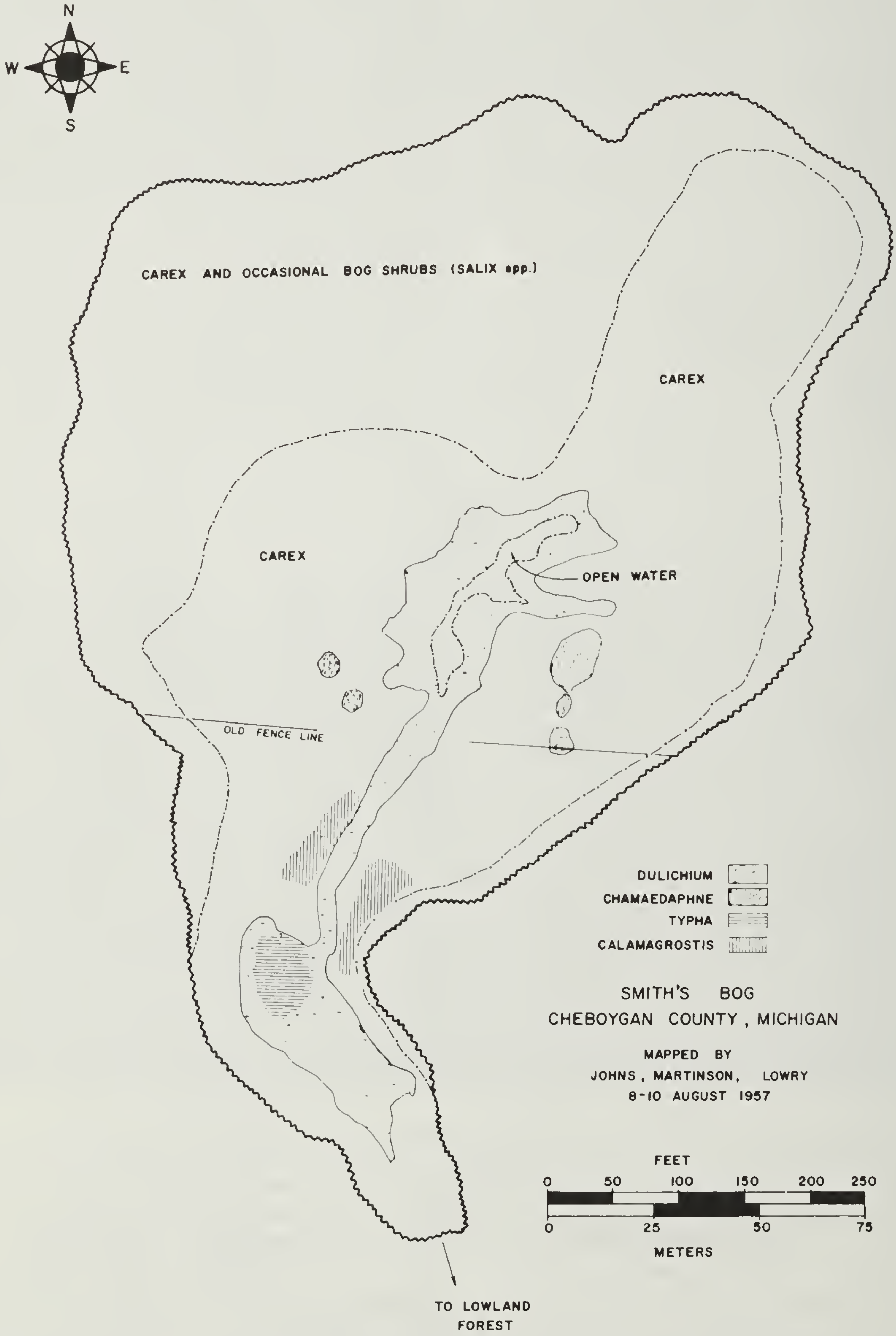
N
W
E
S
CAREX AND OCCASIONAL BOG SHRUBS (SALIX spp.)
CAREX
CAREX
OPEN WATER
OLD FENCE LINE
DULICHIUM
CHAMAEDAPHNE
TYPHA
CALAMAGROSTIS
SMITH'S BOG
CHEBOYGAN COUNTY, MICHIGAN
MAPPED BY
JOHNS, MARTINSON, LOWRY
8-10 AUGUST 1957
FEET
0 50 100 150 200 250
0 25 50 75
METERS
TO LOWLAND FOREST

Fig. 3. Predominant vegetation of Smith's Bog, 1957 (Redrawn from Johns, 1966).

variegatum and *Hypericum boreale. Carex lasiocarpa* formed an extensive mat, and *Dulichium arundinaceum* was the next most frequent species in this zone. Occasional clumps of *Calamagrostis canadensis, Chamaedaphne calyculata, Rhynchospora fusca,* and *Typha latifolia* also occurred on the mat. *Salix* spp. completely surrounded the wetland and continued to encroach most heavily in the northern portion (Johns, 1966). No subsequent investigations were conducted on the vegetation until this study.

During July, 1975, two teams equipped with transits and stadia rods mapped major features of the bog, such as shoreline, open-water boundary, and obvious vegetation zones. Sightings were plotted on quadrant paper (scale: 1 inch = 50 feet). Overall boundaries were drawn on the basis of these points, and a compass and tape were used to map the more detailed features of the vegetation. A large shrubby area in the northern portion of the bog was too complex to be mapped by these methods, and so a transect was taken and all species found in every fifth square meter were identified and tabulated in the field. The most common species were listed on the map. Any plants of questionable identity were collected for further scrutiny. Vegetation maps from Woollett et al. (1925) and Johns (1966) were redrawn and compared with our 1975 map to assess changes in vegetation (Figs. 2 & 3).

Water chemistry data were obtained to assist in classification of this wetland habitat. Surface water chemistry samples were collected in the open-water pool on 7 and 17 July 1975. Chemical tests were performed in the Biological Station's Stockard Laboratory, following the methods stated in Bricker & Gannon (1976). Water level fluctuations were considered to have an influence on vegetation composition in Smith's Bog. Consequently, we compiled information on water level fluctuations from recorded observations in the literature (Woollett et al., 1925; Jewell & Brown, 1929; Gates, 1942; Johns, 1966) and in unpublished notes at the Biological Station.

Fifty-two plant taxa were observed in Smith's Bog during late spring and summer, 1975 (Table 1). Eleven previously unreported species were collected. In contrast, 18 species recorded by previous investigators (Woollett et al., 1925; Johns, 1966) were not observed. Predominant species were *Carex lasiocarpa, Dulichium arundinaceum,* and *Salix* spp. (Fig. 4).

Species distribution appeared to be strongly influenced by relative wetness of the habitat. Three zones of vegetation were observed: shrub, mat, and open water. Substrate in the shrub zone consisted of firm soil which was flooded during spring and early summer. The mat substrate was composed of spongy, water-logged soil which remained in this state throughout the summer.

The shrub zone, located primarily in the outermost portions of the bog, was characterized by greatest species richness (Table 1; Fig. 4). *Salix* spp. were predominant in this zone. Although *Chamaedaphne* was found throughout the bog, except in the open-water portion, it was most common in the shrub zone, especially along the edges of the spring high-water mark. *Iris versicolor* flourished in two portions of the shrub zone which dry up during summer (Fig. 4). The main stands were nearly pure, with only occasional small herbs and seedlings intermixed. In addition, patches of *I. versicolor* were scattered in areas shaded by shrubby growth. *Lysimachia terrestris* and *Hypericum virginicum* were the most frequent associates. *Potamogeton gramineus* was found in low spots in

TABLE 1. Plants collected in Smith's Bog and the zones in which they occurred, summer, 1975. Species not previously reported from the bog are marked with an asterisk.

	Shrub	Mat	Open Water
Alopecurus aequalis	X		
Andromeda glaucophylla	X		
**Aronia prunifolia*	X		
Aster sp.	X		
Bidens sp.	X		
**Brasenia schreberi*			X
Calamagrostis canadensis	X		
**Carex bebbii*	X		
C. brunnescens	X		
C. crinita	X	X	
C. lasiocarpa	X	X	
C. stricta	X	X	
C. vesicaria	X		
Carex sp.	X		
Chamaedaphne calyculata	X	X	
Cornus stolonifera	X		
Dryopteris spinulosa	X		
Dulichium arundinaceum	X	X	X
Eleocharis smallii		X	
Galium trifidum	X		
Glyceria borealis	X		X
Hypericum boreale	X		
H. virginicum	X		
Ilex verticillata	X		
Iris versicolor	X	X	
**I. virginica*		X	
Juncus canadensis	X		
Lycopus americanus	X		
Lysimachia terrestris	X		
Nemopanthus mucronatus	X		
Nuphar variegatum			X
Polygonum amphibium	X		X
**P. coccineum*	X		
Potamogeton gramineus	X		
**P. oakesianus*			X
Potentilla palustris	X		
Rhamnus alnifolius	X		
Rubus strigosus	X		
Salix spp.	X	X	
Scirpus cyperinus	X	X	
S. subterminalis			X
**Scutellaria epilobiifolia*	X		
**S. lateriflora*	X		
Sparganium minimum	X	X	X
Sphagnum sp.	X		
Spiraea alba	X		
**Thelypteris palustris*	X		
Typha latifolia	X	X	X
**Utricularia vulgaris*	X		X
Viburnum cassinoides	X		
**V. lentago*	X		
Viola macloskeyi	X		
Totals	46	12	10

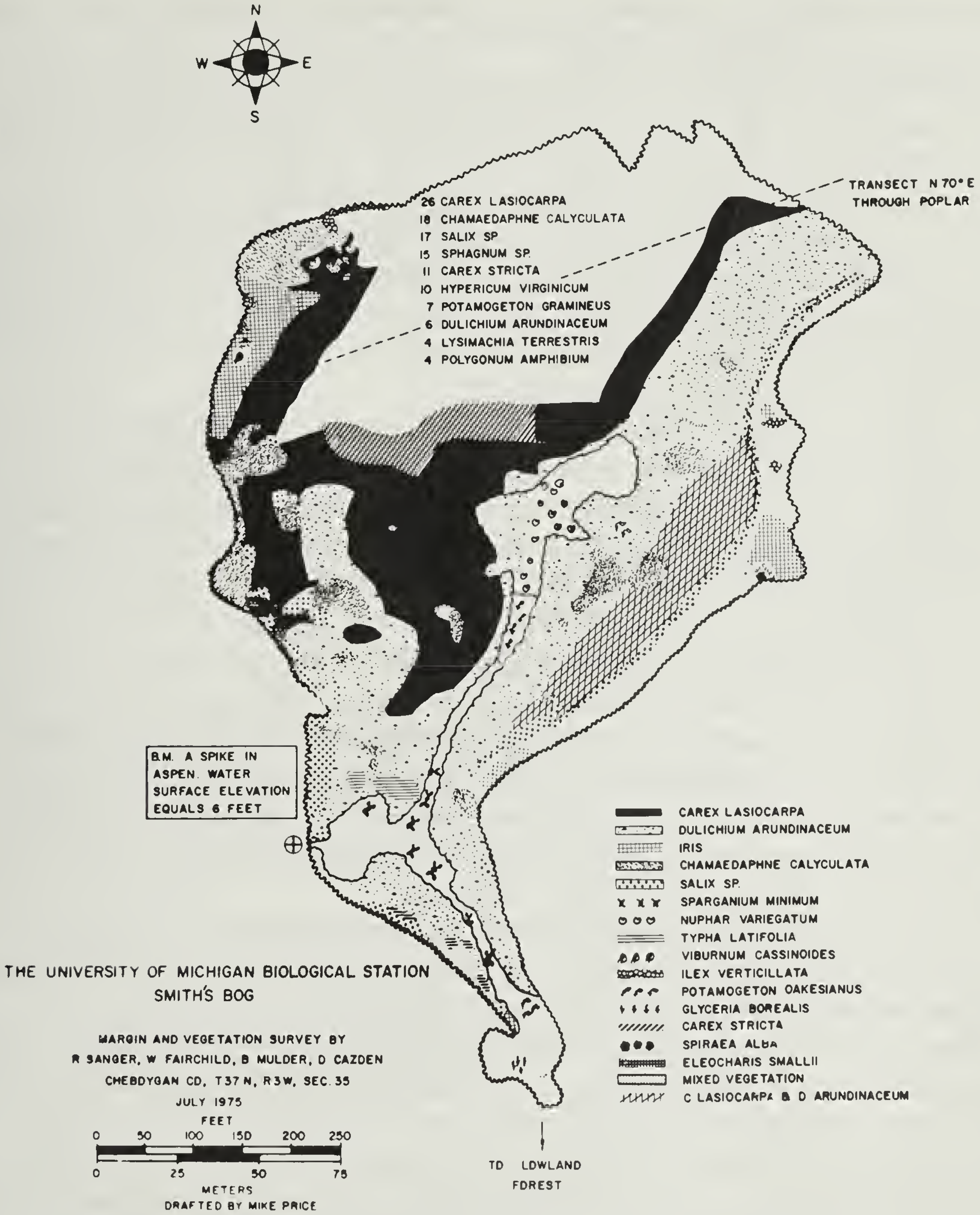
N
W
E
S
26 CAREX LASIOCARPA
18 CHAMAEDAPHNE CALYCULATA
17 SALIX SP.
15 SPHAGNUM SP.
11 CAREX STRICTA
10 HYPERICUM VIRGINICUM
7 POTAMOGETON GRAMINEUS
6 DULICHIUM ARUNDINACEUM
4 LYSIMACHIA TERRESTRIS
4 POLYGONUM AMPHIBIUM
TRANSECT N 70° E THROUGH POPLAR
B.M. A SPIKE IN ASPEN. WATER SURFACE ELEVATION EQUALS 6 FEET
CAREX LASIOCARPA
DULICHIUM ARUNDINACEUM
IRIS
CHAMAEDAPHNE CALYCULATA
SALIX SP.
SPARGANIUM MINIMUM
NUPHAR VARIEGATUM
TYPHA LATIFOLIA
VIBURNUM CASSINOIDES
ILEX VERTICILLATA
POTAMOGETON OAKESIANUS
GLYCERIA BOREALIS
CAREX STRICTA
SPIRAEA ALBA
ELEOCHARIS SMALLII
MIXED VEGETATION
C LASIOCARPA & D ARUNDINACEUM
THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION
SMITH'S BOG
MARGIN AND VEGETATION SURVEY BY
R SANGER, W FAIRCHILD, B MULDER, D CAZDEN
CHEBOYGAN CO, T37 N, R3W, SEC. 35
JULY 1975
FEET
0 50 100 150 200 250
0 25 50 75
METERS
DRAFTED BY MIKE PRICE
TO LOWLAND FOREST

Fig. 4. Predominant vegetation of Smith's Bog, 1975. Shrubby vegetation in the northern portion of the bog was too complex to be mapped. A list of the most frequent species found in 26 one-meter square quadrats along the transect is given. The number of quadrats in which each plant was found is also shown.

the shrub zone but was not present in other zones. It usually produced only floating leaves but submersed leaves were observed in the northeast corner among *Salix* and *Dulichium* in about 0.3 m of water (Fig. 4).

A number of small plants, especially *Hypericum boreale, H. virginicum,* and *Viola macloskeyi,* grew on hummocks formed by *Salix* roots and fallen logs. These hummocks were flooded early in the year by meltwater but became exposed as the water level dropped.

Vegetation on the mat displayed far less diversity than that of the shrub zone (Table 1). *Carex stricta* grew best on flooded portions of the mat. It also grew intermixed with *C. lasiocarpa* in the *Salix* area.

Eleocharis smallii also preferred flooded areas of the mat and occurred in several small scattered clumps.

Although *Dulichium arundinaceum* was observed in all zones, it was most common on the mat in association with *Carex lasiocarpa* (Fig. 4). Areas that appeared to be pure *Carex* from a distance were interspersed with *Dulichium*, which was hidden by the taller *Carex*. *Dulichium* is apparently spreading in this zone and replacing *Carex*. *Dulichium* seedlings were frequently observed growing in floating mats of dead *Carex* leaves. The purest stands of *Dulichium* were in areas covered with standing water throughout the summer. The species also invaded shallow areas in the open water but was less dense there.

Lowest species richness was observed in the open-water zone (Table 1). *Nuphar variegatum* was the predominant species in the deepest (0.7 m) portion (Fig. 4). *Potamogeton oakesianus* was also a prevalent floating-leaved species in open water. Insect damage was frequent in all the floating-leaved species except *P. oakesianus*. *Scirpus subterminalis* was most abundant in the shallow north end of the pond. In contrast, *Sparganium minimum* was most prevalent at the south end. It grew in thick mats in water 0.5 m deep. In addition to this open-water location, *Sparganium* was scattered about the mat and shrub zone where there were pockets of standing water. *Brasenia schreberi* and *Polygonum amphibium* were not abundant in open water, but occasional plants were present. *Polygonum* also grew in wetter spots in the shrub zone where it appeared less affected by insect damage.

Typha latifolia was not limited to any of the three zones. It was common in only one spot near open water; it also grew scattered among *Salix* at the north end of the wetland (Fig. 4).

The surface waters of Smith's Bog were soft (total alkalinity of 13.5 mg/l as $CaCO_3$) and slightly acidic (pH of 6.1) in 1975. Nutrient concentrations were generally low (Table 2).

No numerical data exist on water levels in Smith's Bog, but qualitative observations on low and high-water years were correlated with hydrographic records for nearby Douglas Lake and the Straits of Mackinac (Fig. 5).

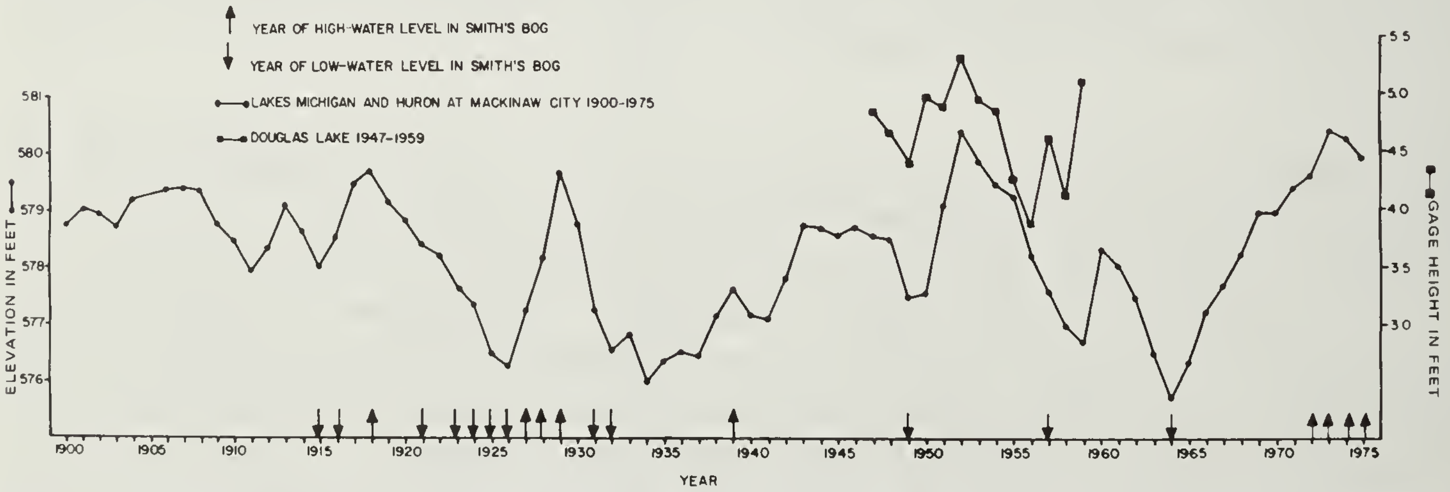

Fig. 5. Surface water level fluctuations near Smith's Bog at Douglas Lake and in the Straits of Mackinac. Qualitative observations on water levels in Smith's Bog were obtained in Woollett et al. (1925); Jewell and Brown (1929); Gates (1942); Johns (1966); and Biological Station unpublished data.

TABLE 2. Chemical composition of surface water in the open water portion of Smith's Bog. Results are average values from samples collected on 7 and 14 July 1975.

Dissolved Oxygen (mg/l)	7.1
Dissolved Oxygen (% sat.)	83.0
pH	6.1
Total Alkalinity (mg/l as $CaCO_3$)	13.5
Specific Conductance (μmhos/cm @ 25 c)	30.2
Chloride (mg/l)	1.2
Calcium (mg/l)	4.0
Magnesium (mg/l)	1.6
Potassium (mg/l)	0.5
Sodium (mg/l)	0.4
Ammonia-Nitrogen (μg/l)	41.7
(Nitrate + Nitrite)-Nitrogen (μg/l)	2.5
Soluble Phosphorus (μg/l)	9.8
Total Phosphorus (μg/l)	17.0
Silica (μg/l as Si)	251.2

DISCUSSION

The abundance of true aquatic species has increased in Smith's Bog, although the open-water area has become considerably reduced since 1924. Four additional aquatic species *(Brasenia schreberi, Potamogeton oakesianus, Scirpus subterminalis,* and *Utricularia vulgaris)* have become established.

Forest fires initiated these changes through destruction of the *Sphagnum* rim, causing alterations in water chemistry. Prior to the 1916 fire, this wetland contained vegetation most characteristic of bogs (Gates, 1942). However, the presence of species indicative of minerotrophic waters, such as *Calamagrostis canadensis* and *Thuja occidentalis* (Heinselman, 1970), suggests that chemistry and vegetation were somewhat influenced by groundwater inflow even before the major forest fire. The water in the pool was acidic (pH 4) but rose to near pH 7 following firm grounding of the mat in 1921 (Gates, 1942). The rise in pH probably favored decay of organic material and increased availability of nutrients. Loss of the *Sphagnum* mat permitted greater inflow of groundwater, and cations were no longer selectively absorbed by *Sphagnum.* Both of these factors would tend to increase the ionic content of the water. These changes in water chemistry apparently were at least partially responsible for a shift in species composition of the vegetation.

The present chemical content of the water and predominance of sedges are most characteristic of a fen (Heinselman, 1963; Jeglum et al., 1974; Moore & Bellamy, 1974). Consequently, Smith's Bog would be more accurately classified as a fen rather than a bog.

Water level fluctuations have also influenced species composition. The original grounding of the *Carex* mat had been subsequently reinforced during low-water periods. The mat had expanded and, therefore, reduced the area of open water. Nevertheless, since the mat became grounded, springtime inundation by meltwater had flooded a greater proportion of the wetland and favored the development of more truly aquatic species and the advancement of *Dulichium* into the pool (Johns, 1966).

Our investigation was conducted during a high-water period. Flooding had apparently caused deterioration of the *Carex* mat since *Carex lasiocarpa* had decreased in area and density. Typical bog species, such as *Menyanthes trifoliata, Scheuchzeria palustris,* and *Eriophorum* sp., that occurred on the mat in 1924 during a low-water cycle (Woollett et al., 1925), were not present in 1975. In 1957, another low-water period, *Calamagrostis canadensis* and *Rhynchospora fusca* were predominant on portions of the mat (Johns, 1966), but in 1975 *Calamagrostis* was extremely rare and *Rhynchospora* was absent.

Other species previously considered secondary in the *Carex* association (Gates, 1942) are invading the mat. *Dulichium arundinaceum* appears to have thrived during recent flooded conditions. It was found throughout the *Carex* mat in 1975. A large, pure stand of *Carex* which occurred in the north-central portion of Smith's Bog in 1924 has been entirely replaced by *Dulichium.* The few patches of *Iris versicolor* observed in 1924 have expanded so that they now form a continuous clump 68.6 m (225 feet) long. New patches have become established on the outer edges of the flooded area. Furthermore, other species that were not previously included in the *Carex* association, such as *Eleocharis smallii, Rubus strigosus, Sparganium minimum,* and *Typha latifolia,* have invaded the mat.

Succession of vegetation appears to be cyclical rather than unidirectional. The original grounding of the mat has been subsequently reinforced during low-water periods but inhibited during high-water cycles. As a result of water-level fluctuations, succession from aquatic to terrestrial habitat has proceeded at a much slower rate in Smith's Bog than anticipated by previous investigators. Similarly, the importance of water-level fluctuations on vegetation succession has recently been noted in other wetland habitats of the Great Lakes region (Buell et al., 1968; Heinselman, 1970; Schwintzer & Williams, 1974; Schwintzer, 1978).

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AN EXPANDED DESCRIPTION OF SPHAGNUM SPLENDENS[1]

Howard Crum

University Herbarium
University of Michigan
Ann Arbor, 48109

The peat mosses of the more northerly parts of North America, including the Great Lakes-St. Lawrence region, are generally widespread and in most cases nearly ubiquitous across the top of the world. Some, however, are disjunctive in oceanic or mountainous areas of Europe, Asia, or both. A very few rarities of arctic or subarctic distribution also occur in disjointed ranges, in scattered Eurasian localities. In view of such a tendency for the species of *Sphagnum* to be widely distributed added to a tendency for botanists to neglect or ignore them, it seems desirable to publicize one of the least known of the American species, *S. splendens* Maass. That species, collected only once, in the province of Quebec, could easily occur elsewhere in Canada and adjacent states and very likely in the region of the Great Lakes.

The type collection of *S. splendens,* now deposited at the National Herbarium of Canada, was for many years lost. It was recently relocated and made available to me by Dr. Wolfgang Maass of the National Research Council in Halifax. It was he who collected the material and described it as new. The most outstanding and truly interesting feature of the species is the absence of the ring-like thickenings that normally reinforce the walls of the large, empty water storage cells of the branch leaves of *Sphagnum*. (The accompanying photographs showing this feature, figures 10 and 11, were given me by Robert Gauthier of the Université Laval in Quebec. Dr. Maass, 1967a, published similar photographs with the

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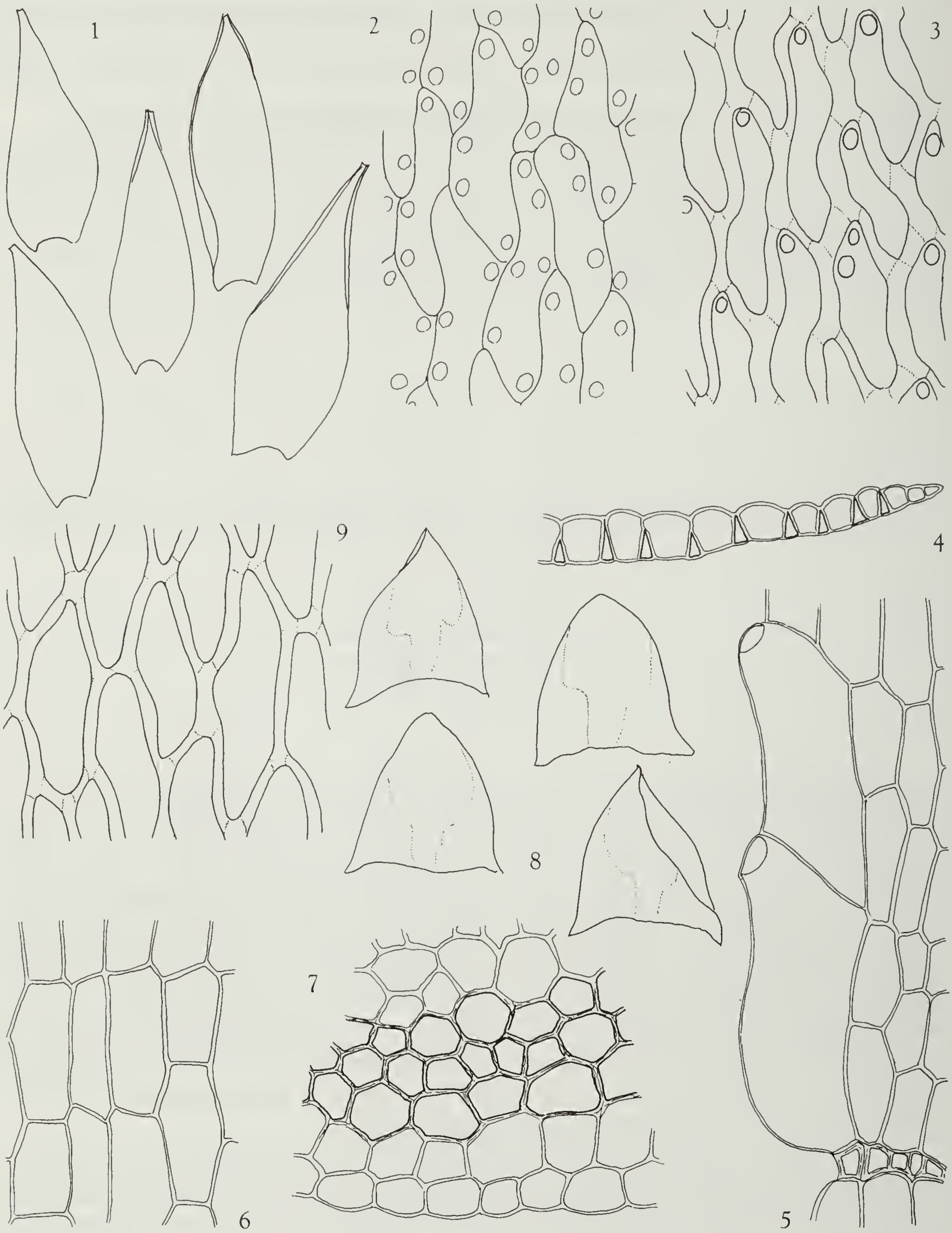
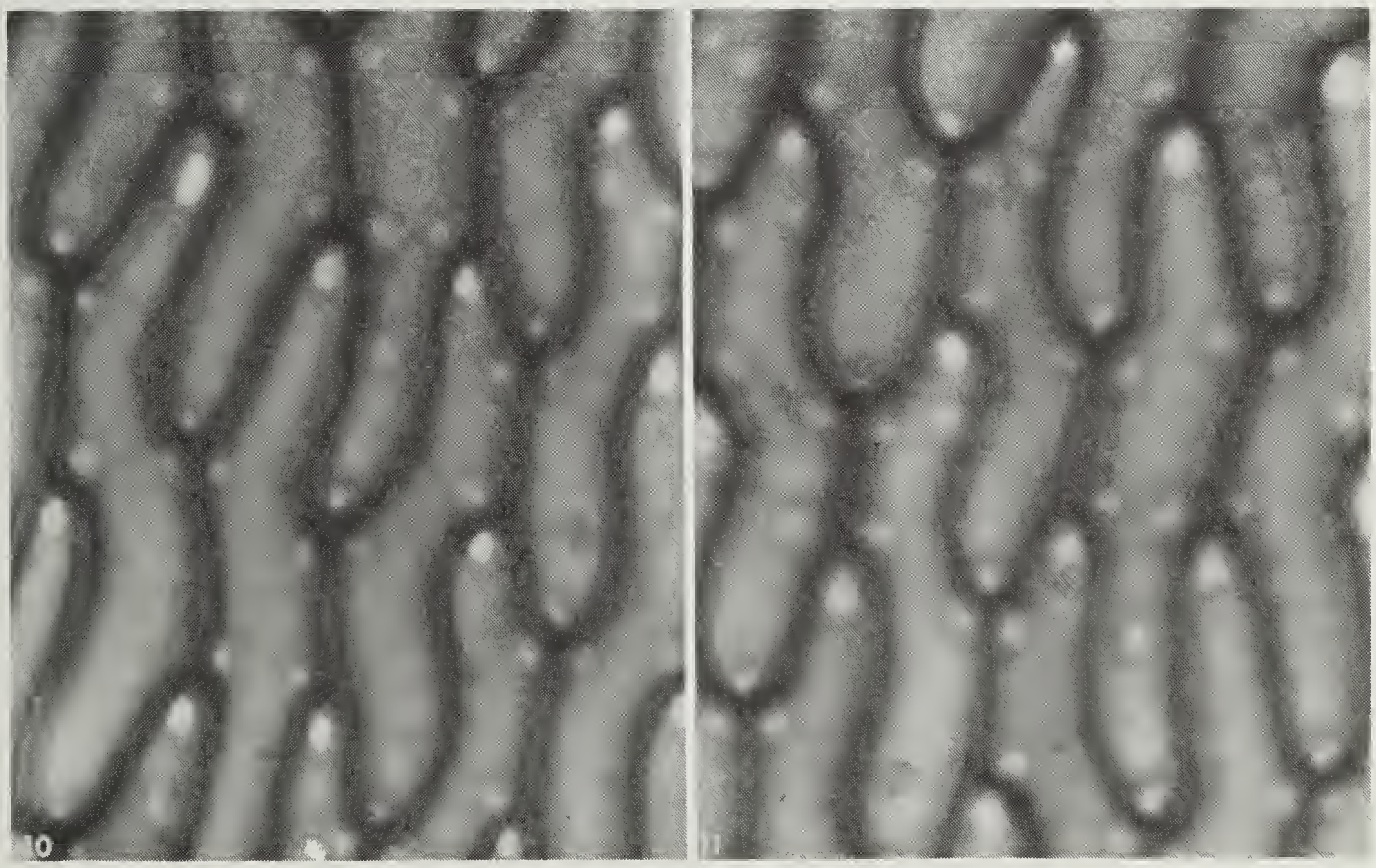


Figs. 1-9. *Sphagnum splendens*. 1. Branch leaves, moist, ×4. 2. Cells of branch leaf, inner surface, ×340. 3. Cells on branch leaf, outer surface, ×340. 4. Cross-section of branch leaf, ×340. 5. Cortical cells of branch, surface view, ×340. 6. Cortical cells of stem, surface view, ×340. 7. Portion of stem in cross-section, ×340. 8. Stem leaves, ×4. 9. Cells of stem leaf, ×340.

original description.) The only other species that lack such reinforcing fibrils are apparently all aquatics: *S. macrophyllum* Bernh. *ex* Brid. (of the Atlantic and Gulf Coastal Plains of eastern North America), *S. sericeum* C. M. (of Java and Sumatra), and *S. efibrillosum* Andrews (of New Guinea). *Sphagnum splendens* probably grows submerged during part of the growth season. It was found intimately mixed with *Sphagnum fallax* and the liverwort *Cladopodiella fluitans*, which grow in wet hollows but normally above the water level, as well as *S. majus*, which grows in places submerged early in the year but drying out as the summer progresses. In *S. macrophyllum,* occasional cells are fibrillose; in *S. splendens* ghostly suggestions of fibrils may be made evident by staining (see fig. 10), and rarely some few cells show one or a few fibrils nearly normal in development. It appears thus that the absence of fibrils is a derived character associated with inundation.

The original description, skeletal in nature, provides only a contrast between *S. splendens* and *S. fallax*.

Sphagnum splendens Maass, Bryol. 70:193. 1967.—Plants of moderate size, pale-brown, somewhat shiny when dry. Apical bud not enlarged; young pendent branches, as viewed between the rays of the capitulum, in pairs. Wood cylinder of stem yellowish; cortical cells moderately enlarged in 3-4 layers, rectangular in outline (2-5:1), with somewhat thickened walls. Stem leaves decurved, oblong-triangular, broadly and bluntly pointed but generally concave-apiculate in appearance, with linear cells forming a border of several rows above but occuping much of the leaf base; hyaline cells undivided, without fibrils or pores. Branches in fascicles of 4 (2 spreading and 2 pendent); cortical cells in a single layer, the retort cells often one above another, with short and inconspicuous necks. Branch leaves oblong-lanceolate, gradually narrowed to a concave apex, loosely appressed with tips somewhat spreading or slightly recurved and not at all undulate when dry, more concave and erect-spreading when moist, those of the youngest branches of the capitulum in spiral rows, bordered by 2-3 rows of linear cells, entire except at the narrow, truncate apex; hyaline cells convex on the inner surface, plane on the outer, without fibrils or pores (or with mere suggestions of fibrils of blurred contour, especially on the outer surface, rarely with an occasional fibril of more distinct structure), on the outer surface with a single, fairly large, rounded apical pore (rarely with 2-3 additional rounded pores in corners and elsewhere) and



Figs. 10-11. *Sphagnum splendens*. 10. Cells of branch leaf, outer surface. 11. Cells of branch leaf, inner surface.

occasional membrane pleats, on the inner surface with 4-8 rounded pores of medium size and thin margins at corners and along commissures, the apical pore often larger; green cells in cross-section isosceles-triangular, broadly exposed on the outer surface, with the apex usually reaching the inner surface, but sometimes only extending midway. Inflorescences and sporophytes unknown.—Quebec, Abitibi Co., 50 ± 6 miles W. of Chapais with *Sphagnum dusenii, S. recurvum* var. *mucronatum* [= *S. fallax*], 5.7.1965, *W. Maass in herb.* CAN.

Hintikka (1972) has demonstrated that under certain conditions of culture *Sphagnum fallax* may produce leaves showing no differentiation of the hyaline, water-storage cells from the green cells that normally enclose them in a network. *Sphagnum macrophyllum,* which also lacks fibrils, shows in nature a considerable tendency for hyaline cells to lack pores. In fact, in the var. *burinense* the hyaline cells are scarcely differentiated in shape, size, or porosity (Maass, 1967). Only a few plants of *S. splendens* are represented in the type collection. They are quite well developed, and in spite of obvious resemblance to *S. fallax,* with which they grew, there is no reason to think of them as atypical, ecomorphic expressions of that species. Both *S. fallax* and *S. majus* occurring in the collection show a normal development of fibrils. It appears therefore that *S. splendens* is genetically based, rather than an aquatic form of freakish occurrence, and therefore worthy of recognition. As in *S. fallax,* the young pendent branches, as viewed between the rays of the capitulum, seem to be in pairs. The overall aspect of the plants, as well as the shape and structure of stem leaves and the nature and distribution of pores on both surfaces of branch leaves, witness a relationship to *S. fallax.* The plants can be sorted out from those of *S. fallax,* admittedly with difficulty, because their leaves are only slightly recurved at the tips and not at all undulate at the margins when dry. Furthermore, on drying the leaves appear somewhat shiny (as the epithet indicates) and have, as seen by a dissecting microscope, a broadly meshed, reticulate texture. (In the one collection available, the plants are a paler, more delicate shade of brown than those of *S. fallax* mingled with them.)

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FRUITING IN RELATION TO SEX RATIOS IN COLONIES OF PLEUROZIUM SCHREBERI IN NORTHERN MICHIGAN

Ann Stoneburner

Dept. of Botany, Duke University
Durham, North Carolina 27706[1]

Although some species of dioicous mosses fruit freely, others infrequently produce sporophytes. Infrequency of sporophyte production has been investigated in a number of species. Lack of fruiting within a colony is generally attributed to an inequality in numbers of male and female plants or complete segregation of the sexes into separated colonies. The majority of species investigated have been acrocarpous. Fewer studies have dealt with pleurocarpous mosses, perhaps due in part to interlacing, prostrate branches which make it difficult to differentiate separate plants. The present study investigates the relationship between frequencies of fruiting and the relative frequencies of male and female plants in colonies of a pleurocarp, *Pleurozium schreberi* (Brid.) Mitt.

Longton (1976), in a survey of reproductive biology of bryophytes, reviewed the literature with reference to sex ratios in moss populations. Low levels of fruiting have been attributed to a rarity of male plants in populations of *Climacium dendroides* (Bedford, 1938), *Breutelia arcuata* (Bedford, 1940), *Mnium undulatum* (Lacey, 1950; DeSloover, 1966; Newton, 1971), *Pleurozium schreberi* (Longton & Greene, 1969b), and *Rhytidiadelphus triquetrus* (Riemann, 1972). Populations in which female plants outnumber males were reported in *Rhacomitrium lanuginosum* (Tallis, 1957). Segregation of sexes was also suggested to explain infrequency of sporophytes in a number of British dioicous mosses (Gemmell, 1950) and in *Bryoxiphium norvegicum* (Hague & Welch, 1951), as well as several Asiatic species (Iwatsuki, 1972). Absence of fruiting in some colonies of *Polytrichum alpestre (P. strictum)* on South Georgia was due primarily to segregation of male and female plants (Longton & Greene, 1967).

Because gamete dispersal distances are presumed to be quite limited, spatial distribution of the sexes is also influential in determining levels of sporophyte production. Bedford (1938) reported for *Climacium dendroides* that female plants with sporophytes were never more than 7.5 cm from the nearest male. A fertilization range of 7 to 10 cm was estimated for *Pleurozium schreberi* in Great Britain (Longton & Greene, 1969b). In *Rhytidiadelphus triquetrus* fruiting females were not found when distances to the nearest male exceeded 6 cm (Riemann, 1972). Brodie (1951) measured a distance of 60 cm for sperm experimentally dispersed from male splash cups of *Polytrichum ohioense*. Distances between fruiting females and the nearest male ranged up to 75 cm in colonies of *P. strictum* (Longton & Greene, 1967). The range of sperm dispersal in populations of *Dawsonia superba* was reported to be 1.5 to 2 m, with a maximum splash distance of 2.3 m for sperm experimentally dispersed from male splash cups (Clayton-Greene et al., 1977). Wyatt (1977), in a study of spatial distribution of the sexes in populations of *Atrichum angustatum,* concluded that sex ratios and spatial patterns largely determine levels of fruiting.

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[1] Mailing address: Dept. of Biology, Texas A & M University, College Station 77843

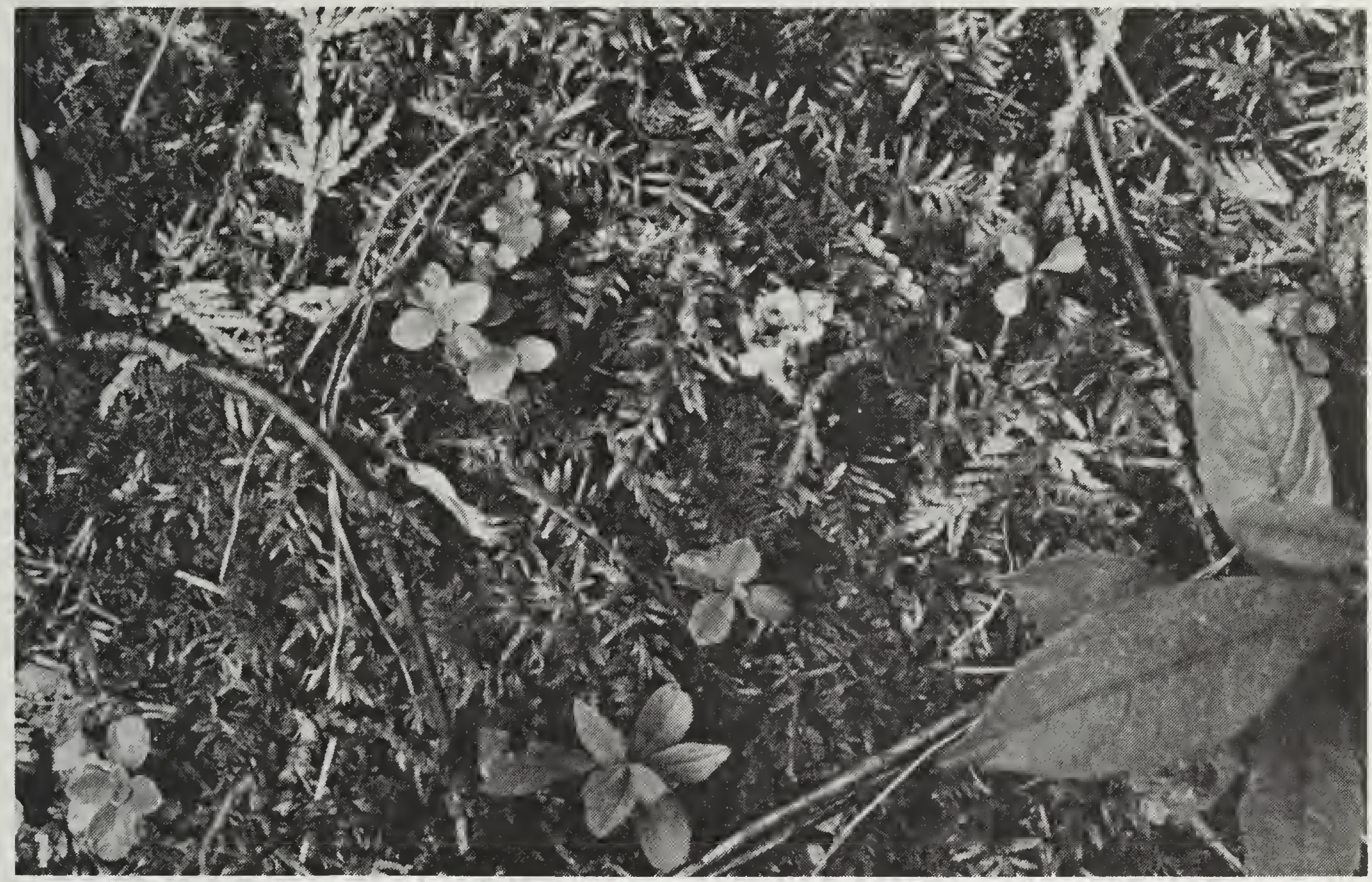
Few attempts have been made to explain mechanisms responsible for nonrandom distribution of sexes and disparity of sex ratios. Unisexual colonies or unequal sex ratios within a colony could arise from environmental stress during crucial developmental periods or from extensive vegetative propagation. Greater frequency of female plants in *Mnium undulatum* was attributed by Newton (1972) to developmental changes occurring between spore formation and early protonematal growth. During this period development of male gametophores was reduced substantially, according to Newton. Wyatt (1977), in his study of sex ratios in *Atrichum angustatum,* discounted differences in microsites as an explanation for unequal sex ratios. He suggested unequal ratios arise through vegetative propagation of unisexual clones.

Pleurozium schreberi was investigated because, while this moss fruits rather infrequently in eastern North America (Longton & Greene, 1969b), a number of colonies were located in northern Michigan in which sporophytes of both current and previous reproductive cycles were found. Comparisons were made between the relative frequencies of the sexes and stages of the life history observed in *Pleurozium* populations in northern Michigan and those reported for British and European populations.

Pleurozium is circumpolar and associated with a northern or boreal flora (Fig. 1). In North America, it is distributed across the continent from Alaska to Greenland and south to the mountains of Virginia, North Carolina, Tennessee, Arkansas, Colorado, Idaho, and Oregon. In the Mackinac Straits area of Michigan, *Pleurozium* is found in dry, open woods and also in wet, coniferous swamps.

The study was conducted at the University of Michigan Biological Station on Douglas Lake in Cheboygan County. Two colonies which possessed numerous sporophytes were sampled in a preliminary investigation of the distribution of sexes within fruiting populations. The colonies were located next to one another on an open, north-facing roadbank (Fig. 2). The area was at the edge of an oak-aspen woodland, adjacent to the campus of the Station and close to the dining hall. The colonies were sampled in the following manner: A 1 m^2 string frame marked in 0.5 dm intervals was anchored over the approximate center of each colony. Ten transects at 2 dm intervals were made across the grid, five from the horizontal axis and five from the vertical. Each transect line was divided into ten 1 dm sections, and a random point was taken in each section. The plant at the sample point was removed, labeled, soaked in water, and examined under a dissecting microscope for the presence of antheridia or archegonia. The sex of each plant was mapped on a scaled version of the grid from which it was collected.

Spatial distribution of the sexes within the mapped colonies was uneven, with clumpings of male or female plants observed. This lack of an even distribution of the sexes



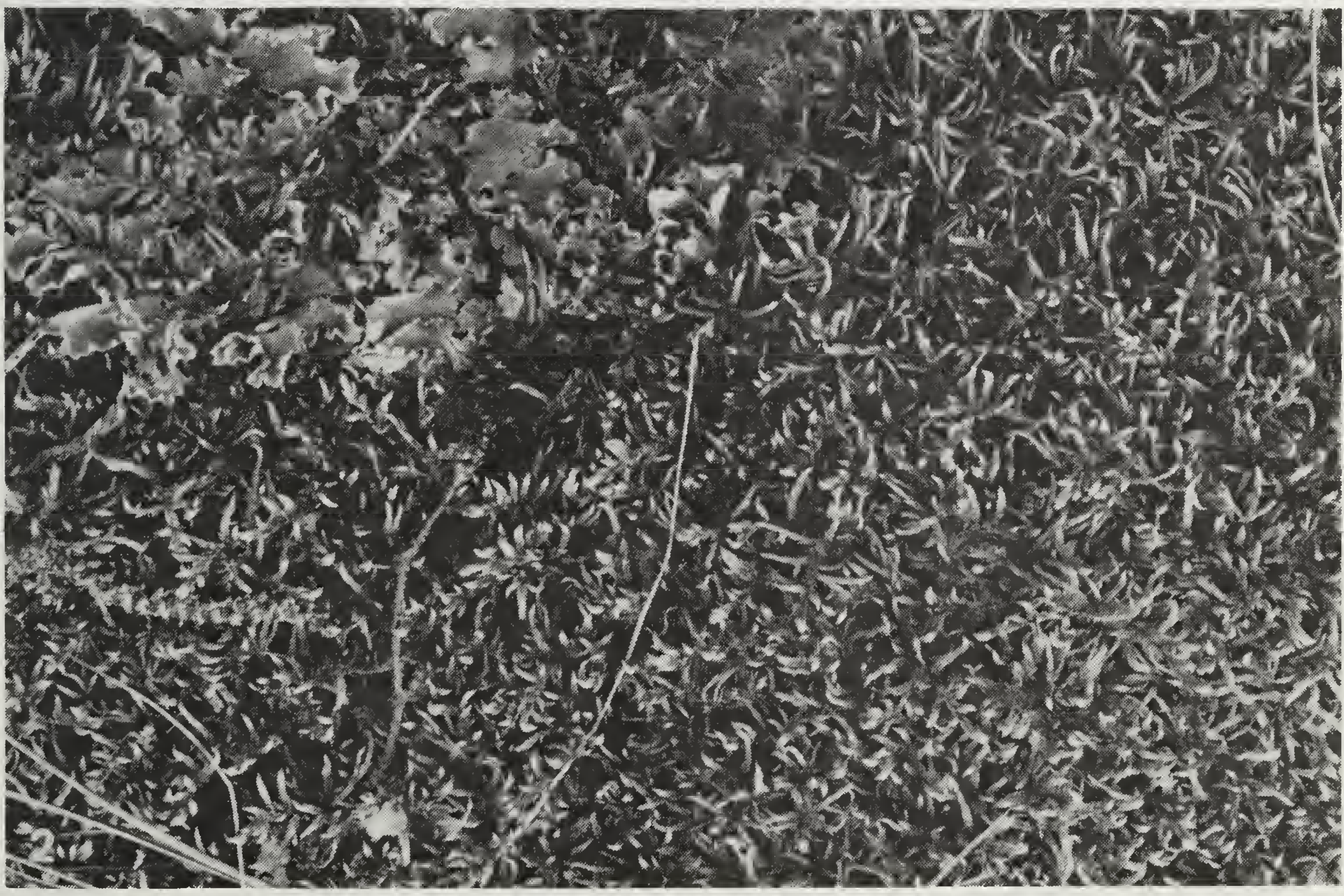


Fig. 1. *Pleurozium schreberi* in a typical habitat in northern Michigan showing pleurocarpous habit with interlacing, prostrate branches. Fig. 2. *Pleurozium schreberi* from the roadbank study site showing density of plants.

indicated a need for further and more intensive sampling of the two colonies. A third fruiting population on level ground was sampled for comparison with the two colonies on slopes. This third colony was located in a jack pine barrens 3 km W of Afton on Hwy. 68 in Cheboygan County. Each of the three populations occurred in relatively dry, open situations.

For each colony, ten random quadrats were sampled from a 1 m^2 grid. The quadrats were selected by pairs of random numbers representing distances measured on the X and Y axes of the grid. Each pair of numbers indicated the location of the upper, righthand corner of the sample quadrat, which was 0.25 dm^2. Prior to examination each sample was soaked in water to reduce fragmentation of the branches. The total number of shoots was determined in each sample, and every second plant was scored for the presence of gametangia or sporophytes. Descriptive terminology of reproductive states follows that of Longton & Greene (1969b): sterile (without gametangia); fertile (with gametangia); barren (without sporophytes); and fruiting (with sporophytes).

Further information on sex ratios in populations of *Pleurozium* was provided by 12 collections from various locations in northern Lower Michigan. For the first 50 plants counted in each collection the sexual and reproductive states were determined, and the number of shoots with newly elongating sporophytes was noted.

Fruiting was greatest in Colony I, 23%, with an over-all male to female ratio of 1:3.33 and the lowest recorded number of sterile plants (Table 1). In Colony II, adjacent to Colony I on the sloping roadbank, the level of fruiting was 5% or about 1/4 that of its neighbor. The number of sterile plants was greater in Colony II, and the number of males declined. Colony III showed the lowest level of fruiting, 1%, despite having the greatest number of fertile male plants. Significantly, its sterile to sexually differentiated ratio was greatest of the three colonies.

Table 2 lists reproductive states of plants scored in each of the random samples. Percentages of the total sample are given for fertile males, fertile (but not fruiting) females, fruiting females, total females, and steriles. Ratios of male to female and sterile to sexually differentiated plants are also listed for each sample.

One-half of the samples from Colony I contained fruiting plants in excess of 10% of total individuals counted. Compared to other samples,

TABLE 1. Total numbers of shoots in each reproductive category, fruiting percentages, and sex ratios for Colonies, I, II, and III.

Colony	Plants Sampled	Plants Examined	Fertile Males	Fertile Females (Not fruiting)	Fruiting Females
I	590	325	50	94	75
II	600	314	5	158	15
III	808	433	136	57	6
Total	1998	1072	191	309	96

Colony	Total Females	Steriles	Percent Fruiting	Male: Female Ratio	Sterile: Sexual Ratio
I	169	106	23	1:3.33	1:2.08
II	173	136	5	1:33.33	1:1.32
III	63	234	1	2.16:1	1.18:1
Total	405	476			
Mean			9	1:2.13	1:1.25

TABLE 2. Percentages of fertile shoots and sex ratios in samples from Colonies I, II, and III ($\bar{x}$ = mean).

		Males	Fertile Females (not fruiting)	Fruiting Females	Total Females	Steriles	Male: Female Ratio	Sterile: Sexual Ratio
Samples Colony I	1	21	4	47	51	28	1:2.44	1:2.56
	2	9	29	45	73	18	1:8.33	1:4.55
	3	15	29	32	62	24	1:4.17	1:3.23
	4	31	16	16	31	38	1:1	1:1.64
	5	28	28	11	39	33	1:1.39	1:2.04
	6	0	0	9	9	91	—	10.11:1
	7	2	84	4	88	10	1:50	1:9.09
	8	0	0	0	0	100	—	—
	9	33	0	0	0	67	—	2.03:1
	10	0	38	0	38	62	—	1.63:1
	$\bar{x}$	13.90	22.80	16.40	39.10	47.10	1:2.78	1.12:1
Samples Colony II	1	13	37	33	70	17	1:5.26	1:5.00
	2	0	45	7	52	48	—	1:1.09
	3	3	52	3	55	42	1:20	1:1.39
	4	0	43	2	45	55	—	1.22:1
	5	0	50	0	50	50	—	1:1
	6	0	20	0	20	80	—	4.00:1
	7	0	29	0	29	71	—	2.45:1
	8	0	85	0	85	15	—	1:5.56
	9	0	38	0	38	62	—	1.63:1
	10	0	69	0	69	31	—	1:2.22
	$\bar{x}$	1.60	46.80	4.50	51.30	47.10	1:33.33	1:1.12
Samples Colony III	1	23	16	5	21	56	1.09:1	1.27:1
	2	20	46	3	49	31	1:2.44	1:2.22
	3	27	20	3	23	50	1.17:1	1:1
	4	20	36	2	39	41	1:1.96	1:1.45
	5	50	0	0	0	50	—	1:1
	6	67	3	0	3	30	22.30:1	1:2.33
	7	36	8	0	8	56	4.50:1	1.27:1
	8	34	2	0	2	64	17.00:1	1.78:1
	9	19	0	0	0	81	—	4.26:1
	10	40	0	0	0	60	—	1.50:1
	$\bar{x}$	33.60	13.10	1.30	14.50	51.90	2.32:1	1.36:1

these were distinguished by low ratios of sterile to sexually differentiated plants, and more balanced sex ratios. Of the five remaining quadrats which were barren or had less than 10% fruiting, three contained no males or had a male to female ratio of 1:50; one sample contained no females; and one contained only sterile plants.

In Colony II only one sample demonstrated fruiting in excess of 10%. Although it had a low male to female ratio, it had an equally low ratio of sterile to sexually differentiated plants. For the other nine samples, there was a complete absence of males or, as in one case, a male to female ratio of 1:20.

In Colony III, none of the samples reached a 10% level of fruiting. The four samples in which fruiting occurred had sex ratios which approached unity. The remaining six samples were barren with females either absent or nearly so.

In three of the quadrat samples, in which low incidences of fruiting were recorded, no male shoots were counted. This may be the chance result of sexing every second plant, or it may demonstrate a difficulty inherent with the quadrat sampling method, i.e., the likelihood of male plants from outside the quadrat effecting fertilizations within the sample.

Samples from field collections elsewhere provided frequencies of reproductive states similar to those for the colonies (Table 3). In seven barren samples one or the other or both sexes were absent. Of the remaining five samples which contained sporophytes, a relatively high degree of fruiting occurred, with comparably balanced male to female ratios and lower sterile to sexually differentiated ones.

Three factors appear to be responsible for the varying degrees of fruiting observed in *Pleurozium* populations in northern Lower Michigan: the ratio of sexes within a bisexual population, spatial segregation of the sexes into unisexual clumps, and the ratio of sterile to sexually differentiated plants within a population.

For Colony I, the determining factor in production of sporophytes appears to be the ratio of male to female plants. Both Colonies II and III had heavily biased sex ratios, in favor of female plants in Colony II and males in Colony III. As samples from each colony show, even within bisexual populations the sexes may be segregated into unisexual clumps. Such spatial separation of sexes within a population will lead to a reduction in fruiting. In each colony, it is likely that sterile plants act as physical barriers to dispersal of male gametes and increase the gametic dispersal distances between sexually differentiated plants. These effects are in

TABLE 3. Percentages of fertile shoots and sex ratios from 12 field samples ($\bar{x}$ = mean).

Field Collection Sample	Males	Fertile Females (not fruiting)	Fruiting Females	Total Females	Steriles	Male: Female Ratio	Sterile: Sexual Ratio
1	16	36	40	76	8	1:4.76	1:11.11
2	56	14	14	28	16	2.00:1	1:5.26
3	39	9	32	41	20	1:1.05	1:4.00
4	48	0	24	24	28	2.00:1	1:2.56
5	18	24	22	46	36	1:2.56	1:1.79
6	16	0	0	0	84	—	5.25:1
7	0	2	0	2	98	—	49.00:1
8	6	0	0	0	94	—	15.67:1
9	0	6	0	6	94	—	15.67:1
10	0	10	0	10	90	—	9.00:1
11	0	0	0	0	100	—	—
12	28	4	0	4	68	7.00:1	2.13:1
$\bar{x}$	18.92	8.75	11.00	19.75	61.33	1:1.04	1.59:1

addition to the obvious reduction in effective sex ratios and levels of fruiting by the presence of sterile plants in a colony.

Based on total numbers or mean percentages of each shoot type and mean ratios for colonies and field samples, it appears that ratios of male to female and sterile to sexually differentiated individuals approach unity in northern Michigan. The apparent equality in mean numbers does not reflect the local clumping of male versus female and sterile versus sexual plants.

It was considered possible, at the beginning of this study, that mesotopographic relief might enhance water-mediated sperm dispersal and consequently increase sporophyte production. Colony I, on the sloping bank, had the highest percentage of fruiting; however, Colony II, next to Colony I on the slope, demonstrated a low percentage of fruiting, comparable to Colony III on level ground. Apparently, the ratio of male to female is of primary importance in determining levels of sporophyte production.

Although *Pleurozium* does not produce gemmules or, as far as known, other organized means for asexual reproduction, the main stems are fragile and easily fragment, especially when dry. Such fragmentation could lead to the formation of large asexual colonies. Through dispersal and establishment of spores or fragments and subsequent cloning by the founding plants, unisexual colonies could become established. Such a description is applicable to Colonies II and III. It is obvious that as sexual parity is approached within a population, as in Colony I, effective fertilizations and the production of sporophytes increase.

An extensive study of the relationship between the geographic distribution of the sexes and sporophyte production in *Pleurozium* was made in Great Britain (Longton & Greene, 1969b). Fruiting populations were reported to be widespread in northern Scotland and across southern Scandinavia, but uncommon to rare in southern Britain. Reduction in sporophyte numbers was correlated with a rarity of male plants. While plants bearing archegonia were observed in abundance, male plants were uncommon and found principally in colonies within coniferous plantations.

Longton & Greene (1969a) reported the following life history for British populations: *Pleurozium,* a dioicous moss with perennial stems, produces large numbers of male inflorescences or perigonia on lateral branches and female buds or perichaetia in lesser quantities on main stems. Inflorescences, produced in autumn, overwinter in the juvenile stage. Fertilization occurs in April and May, and immature sporophytes can be observed throughout the summer months. Developing sporophytes are easily recognized by the swollen venter of the enlarged archegonium. In August, elongation of the setae begins. Fully developed capsules with intact opercula are not found until October. Spores are shed between January and April, nine to twelve months after fertilization.

Other studies of the reproductive cycle of *Pleurozium* were reviewed by Longton & Greene (1969a): in Sweden, fertilization occurred in July

(Arnell, 1905); in Germany, during May (Grimme, 1903; Krieger, 1915); and in Holland, from April to June (van der Wijk, 1960). In conflict with these observations was Barkman's (1961) report of ripe capsules present throughout the year in Dutch populations. From these descriptions and their own examinations of British, French, Scandinavian, and North American specimens, Longton & Greene (1969a) concluded that *Pleurozium* had a similar maturation cycle throughout its range with variations in timing of individual developmental events probably related to the duration and severity of winter.

The development and maturation of perichaetial and perigonial inflorescences and sporophytes, as studied in July and August in northern Michigan, appear similar to those described for the species in Great Britain (Longton & Greene, 1969a). Numerous observations of archegonia with swollen venters were indicative of recent fertilizations. Perigonial buds, green and fresh in appearance and assumed to be of the present reproductive cycle, were dissected frequently in the scoring process. None of these gametangia contained sperm, again an indication of recent fertilizations. Counts of sporophytes with newly elongating setae frequently exceeded those with dehisced capsules. A cytological investigation of several populations indicated meiosis occurs in late August through early September and that the haploid chromosome number is 5 (Dr. Lewis E. Anderson, pers. comm.). The great majority of capsules from previous reproductive cycles appeared to have completed spore liberation, although a few were observed to contain small numbers of green spores.

Explanations of the origin of large numbers of sterile plants are merely speculative. Environmental stress during crucial developmental periods might prevent production of gametangia in one or both sexes. Newton (1971) found through use of a sex-specific cytological character in *Mnium undulatum* that male plants do not always produce inflorescences and are frequently falsely scored in studies of this sort. However, it may be that failure to reach reproductive maturity is not dependent upon the sex of the individual. Plants which do not produce gametangia may grow in microsites unfavorable for maturation of either sex. Spore germination studies and culturing of protonemata and developing gametophores could yield valuable information on the origin of sterile plants and unequal sex ratios in *Pleurozium* populations.

SUMMARY

The dioicous, pleurocarpous moss, *Pleurozium schreberi,* is considered to fruit rarely in North America. In northern Michigan, a number of fruiting populations were sampled by random quadrats and field collections. Plants were scored for the presence of male or female gametangia and sporophytes. Frequencies of fruiting were related to the relative frequencies of male and female plants. Three factors appear to be responsible for the varying degrees of fruiting observed: the ratio of sexes within a bisexual population, segregation of the sexes into unisexual clumps, and the ratio of sterile to sexually differentiated plants within a population.

Fragmentation of the light, fragile stems is suggested as a possible means of asexual reproduction in *Pleurozium*. Extensive vegetative propagation could lead to the establishment of large unisexual clumps.

Development and maturation of perichaetial and perigonial inflorescences and sporophytes appear similar to those in Great Britain. Green, fresh antheridia empty of sperm, archegonia with swollen venters, sporophytes with newly elongating setae, and sporophytes of previous cycles with dehisced capsules were observed during July and August.

This study was carried out under the direction of Dr. Howard Crum at the University of Michigan Biological Station during the summer of 1976. Helpful criticism or assistance in the field given by Jerry Snider, Christa Schwintzer, Lesley Herbst, David Lane, Jefrey Holcombe, Peter Harley, and Ann Rushing is gratefully acknowledged. Drs. Lewis Anderson, R. E. Longton, and Robert Wyatt offered suggestions on an earlier draft of the manuscript. The photographs in Figures 1 and 2 were made from slides provided by Dr. Crum.

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CONTRIBUTIONS TO BOTANY BY MEMBERS OF THE MICHIGAN BOTANICAL CLUB

William S. Benninghoff

Dept. of Botany and Matthei Botanical Garden
University of Michigan, Ann Arbor, 48109

John H. Beaman

Dept. of Botany, Michigan State University
East Lansing, 48823

Speaking for a group of members, including several of us on the State Board, we urge that Club members apply themselves to efforts that will advance knowledge, as well as appreciation, of the plant life of Michigan. Increase in knowledge of our flora and vegetation cannot be left to the small number of research botanists who make their living at it; progress will be much too slow. Appreciation of wild plants and their habitats fortunately is not left just to the professional teachers. The Club has already made valuable contributions in this direction. Let us put ourselves to the job of improving the amount and quality of information accumulating on our State flora, for cryptogams as well as phanerogams. Members of the National Audubon Society through local chapters in little more than 50 years brought knowledge of bird distributions in the United States to a level rivaling comparable information in Western Europe. Let us work in a similar direction with our State flora.

What can non-professional botanists do that will constitute valuable contributions to knowledge of our flora? Here are some suggestions:

Make a detailed species list for each parcel of stable (persistent, little-changing) vegetation you can visit regularly around the year. When you cannot extend your list further, or need assistance with identifications, invite other Club members to your study area. If there is any uncertainty about identification, make an herbarium specimen which can be shown to other members for precise identification (but be sure not to collect the *only* specimen of a species in the study area). Club officers will tell you where to submit your completed list for the Club archives, and also what information is needed about location, geographic setting, soils, etc.

Make collections of seeds of native plants (and spores of ferns and mosses) for establishment of species in institutional gardens for instructional and research purposes. The Matthaei Botanical Gardens of the University of Michigan also needs clean and pest-free seeds of native plants for the *Index Seminum* list. Each collection of seeds should be made at a single locality (within the same plant community) and as far as possible from a single uniform population of that species.

Make observations of insect visitors and pollinators of native flowering plants. There is very little accurate (and well-documented) information on this subject. Study would probably best be restricted to one species at a time, using a fairly large uniform population (as a species of Hawkweed in an old field) and extending through the entire flowering period. Many of the insects must be collected and prepared in a proper manner and identified by a qualified entomologist if they cannot be accurately identified on sight.

Make observations on the flowering and fruiting of native plants, especially the fruit production of mast-fruiting perennials such as the oaks. The object is to develop well-documented observations of one or several mature and likely-to-persist populations. There is some indication that heavy production of pollen augurs a heavy fruiting; this would be worth testing on appropriate species. The kinds and frequencies of pests (e.g. weevils) and diseases on the fruits and seeds in successive years would be helpful.

Prepare complete phenologic records of individual species with a fairly large population, possibly on an environmental gradient (moisture or shade, for example). Another approach is to make regular observations on the dozen or so most common species in a given plant community. The longer the period of years of observation, the more valuable the record. Such records will probably prove to be valuable indicators of climatic trends, just as the 1000-year record of the flowering of ornamental cherry trees in Japan.

Collect, verify, and record historical accounts of vegetation of specific areas in the past or of changes in vegetation over a given period. Sources may be surveyors' records, land titles, and other land documents, or even oral history by old persons. Of particular concern in Michigan are descriptions of vegetation found by the first or early European settlers in the State, original forests which were clear-cut for timber and fuel wood, and succession after cutting, fires, floods, and other catastrophes.

THE ACCELERATION OF SUCCESSION OF A BIRCH-MAPLE FOREST DUE TO HIGH WIND

Lawrence A. Kapustka[1] and Rudy G. Koch

Dept. of Biology and
Center for Lake Superior Environmental Studies
University of Wisconsin—Superior
Superior, 54880

Ecological succession has been defined as an orderly, progressive, predictable transition of communities through time in response to a changing environment, an ecocline in time (Odum, 1969; Drury & Nisbet, 1973; Whittaker, 1953, 1975). Typically, environmental disturbances, especially catastrophic events, interrupt the successional pattern by reverting the vegetation to an earlier sere or by deflecting the sere into a different successional sequence. In this communication, we present data from a birch-maple forest in northern Wisconsin which indicate that natural perturbations, in this case high winds, may advance the successional process.

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[1] Present address: Dept. of Botany, Miami University, Oxford, Ohio, 45056.

In 1967, a tornado swept through the birch-maple-basswood forests of the Chequemagon National Forest northwest of Drummond, Wisconsin. Salvage lumbering was allowed in much of the affected zone, but in a portion of the forest no clean-up was performed. Our study area was located in a non-salvage area approximately 2 km north of the University of Wisconsin Pigeon Lake Field Station (Bayfield County, T45N, R7W, S25). Three transects were established in the vicinity of the tornado zone. One transect (II) was located in the disturbed area; the remaining two transects (I and III) were in the undisturbed forest adjacent to the disturbed woods. Quadrats (10 m × 10 m) were located at 25 m intervals along the transects. Species identification, DBH, and breakage of the bole were recorded for all living trees ($\leqslant$ 10 cm DBH). In addition, species identification and an approximate DBH were obtained for all downed timber that had been rooted in the quadrats. Saplings and large shrubs ($<$ 10 cm DBH and $>$ 1 m tall) were enumerated by species in a 5 m × 5 m quadrat located inside the larger quadrat. Summary calculations of density, frequency, dominance, relative values, and importance percentage (IP) (Greig-Smith, 1964) were performed. IP in this paper is the mean of the three relative measures.

The undisturbed woods represented by Transects I and III (Table 1) typify birch-maple forests in the mid-stages of development for the region in northern Wisconsin (Curtis, 1959). Transect I is predominantly birch *(Betula papyrifera)* with significant amounts of red maple *(Acer rubrum)* and sugar maple *(A. saccharum)*. Transect III is in an older stand having birch and sugar maple codominant with a minor red oak *(Quercus borealis)* and basswood *(Tilia americana)* element. Size-class (DBH) histograms of the major species (Fig. 1) illustrate the demise of birch and the increase of sugar maple in these stands consistent with the successional pattern.

Transect II may be considered in two ways: (1) the extant forest and (2) the reconstructed forest based on the extant forest plus downed timber. Presently, the forest is dominated by sugar maple with red maple and birch existing as subdominant species and red oak of minor significance. Size-class (DBH) histograms (Fig. 2) suggest a general increase in importance of sugar maple. The reconstructed forest, based on the relative importance of birch and maple, appears intermediate to the stands of Transects I and III. Therefore, comparisons of the current forest to the reconstructed forest to assess the impact of the high winds appear valid.

The downed timber was all $>$ 10 cm DBH as indicated in Fig. 2. Smaller specimens probably represent growth and establishment since the disturbance. It is important to note the selective damage inflicted by the high winds. Birch incurred major loss, whereas red maple experienced limited damage and sugar maple was affected even less. Many of the living maples had one or more upper branches broken by the wind, but the canopies have closed on most of these trees.

Wells (1976) described a correlation between ecomorphological adaptations and successional position. One element of his correlation is the

TABLE 1. Summary of Arborescent Vegetation for the Undisturbed Stands (Transects I and III) and Disturbed Area (Transect II).

Taxa	Density[1] ($M + S_{\bar{x}} \cdot t$)	Basal Area	Freq.	Rel. Freq.	Rel. Den.	Rel. Dom.	I.P.
		TRANSECT I					
Acer saccharum	1.2 ± 0.81	333.17	70	23.3	11.9	14.4	16.5
A. rubrum	1.3 ± 0.88	203.09	60	20.0	12.9	8.8	13.9
Betula papyrifera	6.7 ± 2.69	1497.59	100	33.3	66.3	64.7	54.8
Quercus borealis	0.9 ± 0.63	278.65	70	23.3	8.9	12.1	14.8
		TRANSECT II EXTANT					
Acer saccharum	4.60 ± 3.14	660.60	80	33.3	60.5	52.4	48.7
A. rubrum	1.60 ± 1.52	235.58	60	25.0	21.1	18.7	21.6
Betula papyrifera	1.10 ± 0.86	243.08	70	29.2	14.5	18.7	20.8
Quercus borealis	0.30 ± 0.34	129.16	30	12.5	3.9	10.2	8.9
		TRANSECT II RECONSTRUCTED					
Acer saccharum	5.10 ± 1.62	803.66	80	28.6	39.8	33.6	34.0
A. rubrum	2.30 ± 0.79	322.62	70	25.0	18.0	13.5	18.8
Betula papyrifera	5.1 ± 1.36	1138.88	100	35.7	39.8	47.6	41.0
Quercus borealis	0.30 ± 0.15	129.16	30	10.7	2.3	5.4	6.1
		TRANSECT III					
Acer saccharum	3.57 ± 1.30	1189.47	100	30.4	41.0	37.4	36.3
A. rubrum	0.43 ± 0.49	109.52	42.9	13.1	4.9	3.4	7.1
Betula papyrifera	3.14 ± 3.55	955.25	71.4	21.7	36.1	30.1	29.3
Quercus borealis	0.57 ± 0.49	497.11	57.1	17.4	6.5	15.6	13.2
Tilia americana	1.00 ± 1.08	426.67	57.1	17.4	11.5	13.4	14.1

[1] Mean and Confidence Interval per 100 m^2.

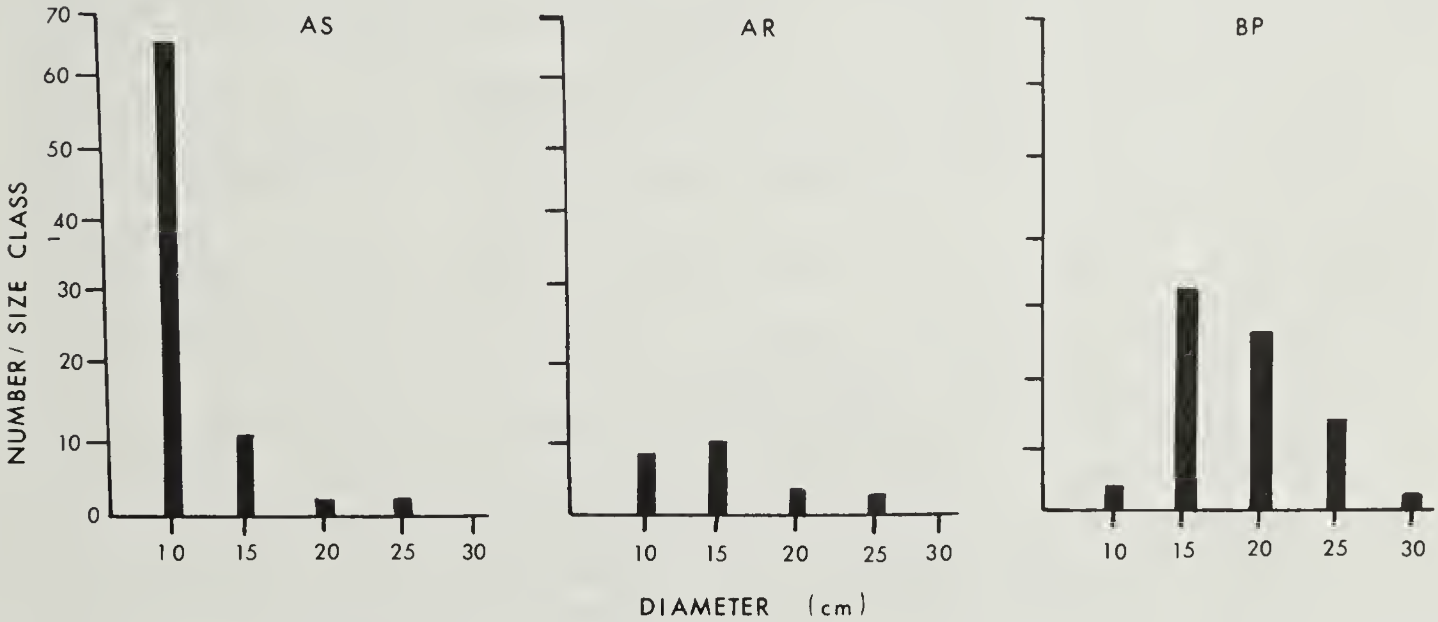

Fig. 1: Size-class (DBH) histograms of Transect I (undisturbed forest). AS = *Acer saccharum*, AR = *A. rubrum*, BP = *Betula papyrifera*.

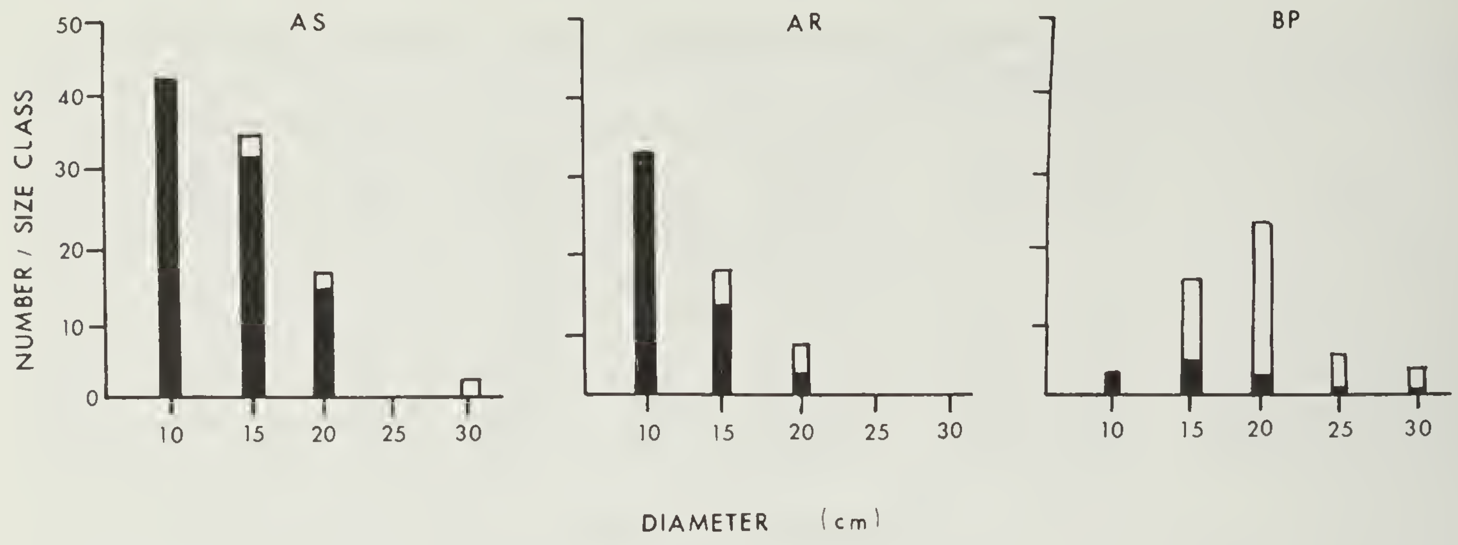

Fig. 2: Size-class (DBH) histograms of Transect II (undisturbed forest). Solid bar (extant forest) superimposed on reconstructed forest (open bar). Abbreviations as in Fig. 1.

strength of wood as measured by the modulus of rupture, a measure of the mechanical strength of wood. The trend is for stronger wood in later successional species. The magnitude of damage to the species in this forest is consistent with the observations of Wells. For the three principle species the modulus of rupture values (K Pa) of green wood are sugar maple, 65,000; red maple, 53,000; and birch 44,000 (U.S. Forest Products Laboratory, 1974). The percentage of trees downed and killed by the winds in Transect II were 9.8, 30.4 and 78.4 for sugar maple, red maple, and birch, respectively. In addition, the percentages of living trees with broken tops were 24.4, 18.8 and 27.3 for the three species, respectively. In Transects I and III only one maple tree was damaged, whereas 6.9% and 15.4% of the birch trees were downed.

In the undisturbed stands only five species other than birches and maples were encountered in the sapling-shrub category. These understory species were *Ostrya virginiana, Abies balsamea, Q. borealis, Dirca palustris,* and *Populus tremuloides.* The disturbed forest, reflecting the temporary open canopy of a few years ago, contained nine associated understory species: *Prunus pennsylvanica, P. virginiana, Cornus stolonifera, Amelanchier spicatum, O. virginiana, Corylus americana, Populus tremuloides, Abies balsamea,* and *Q. borealis.*

Spurr (1956) concluded that a hurricane in New Hampshire (in 1938) initiated the processes of secondary succession in a white pine forest by eliminating the pioneer species and releasing the understory hemlock, beech, and red maple to form a new, lower canopy. The resulting forests contained islands of pioneer species among the more mature forest characteristic of gap-phase regeneration later described by Bray (1958).

The vegetation of the disturbed birch-maple forest has characteristics of a managed forest in which selective harvest has been employed to reduce interference and enhance the development of a particular species. Due to the differential breakage rates of birch and maple, the high winds were effective in eliminating most of the birch component and, in effect, selectively promoting sugar maple in this forest. These differences were maintained by the apparent inability of the birch to regenerate via stump sprouts. Presumably, the growth of associated shrub species led to a rapid closure of the lower canopy, thus preempting subsequent emergence of the shade intolerant birch. Similar forests in the vicinity having occasional aspen trees responded in the usual fashion to disturbance in that large numbers of aspen suckers emerged. Such forests have generally reverted to an earlier successional position. However, in the birch-maple forest (where aspen was not present), the data indicate that the disturbance has advanced the forest toward a terminal or climax community.

SUMMARY

Three transects with a total of 27 quadrats (10 m × 10 m) were used to survey a birch-maple forest, including a portion damaged by a 1967 tornado, north of the University of Wisconsin Pigeon Lake Field Station. Comparisons of community composition (Importance Percentage and size class distribution of each taxa) between the blow-down zone and adjacent undisturbed forest identified a selective elimination of birch and an associated enhancement of sugar maple and red maple resulting from the disturbance. Tree damage was correlated with the modulus of rupture for the species. The data suggest that, unlike most perturbations, this disturbance has advanced the successional process.

The authors extend their gratitude to Patti Olson, Bonnie Heidel, and Lynn Tendrup for assistance in collecting and summarizing the data.

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CONTENTS

The Comparative Ecology and Frequencies of Interspecific Hybridization of Michigan Woodferns
Thomas J. Carlson 47

The Genus Placidiopsis Beltr. (Lichenized Ascomyctes) New to North America as Placidiopsis minor sp. nov.
Richard C. Harris 57

Vegetation Succession in Smith's Bog, Cheboygan County, Michigan
Robert Sanger & John E. Gannon

An Expanded Description of Sphagnum splendens
Howard Crum 69

Fruiting in Relation to Sex Ratios in Colonies of Pleurozium schreberi in Northern Michigan
Ann Stoneburner 73

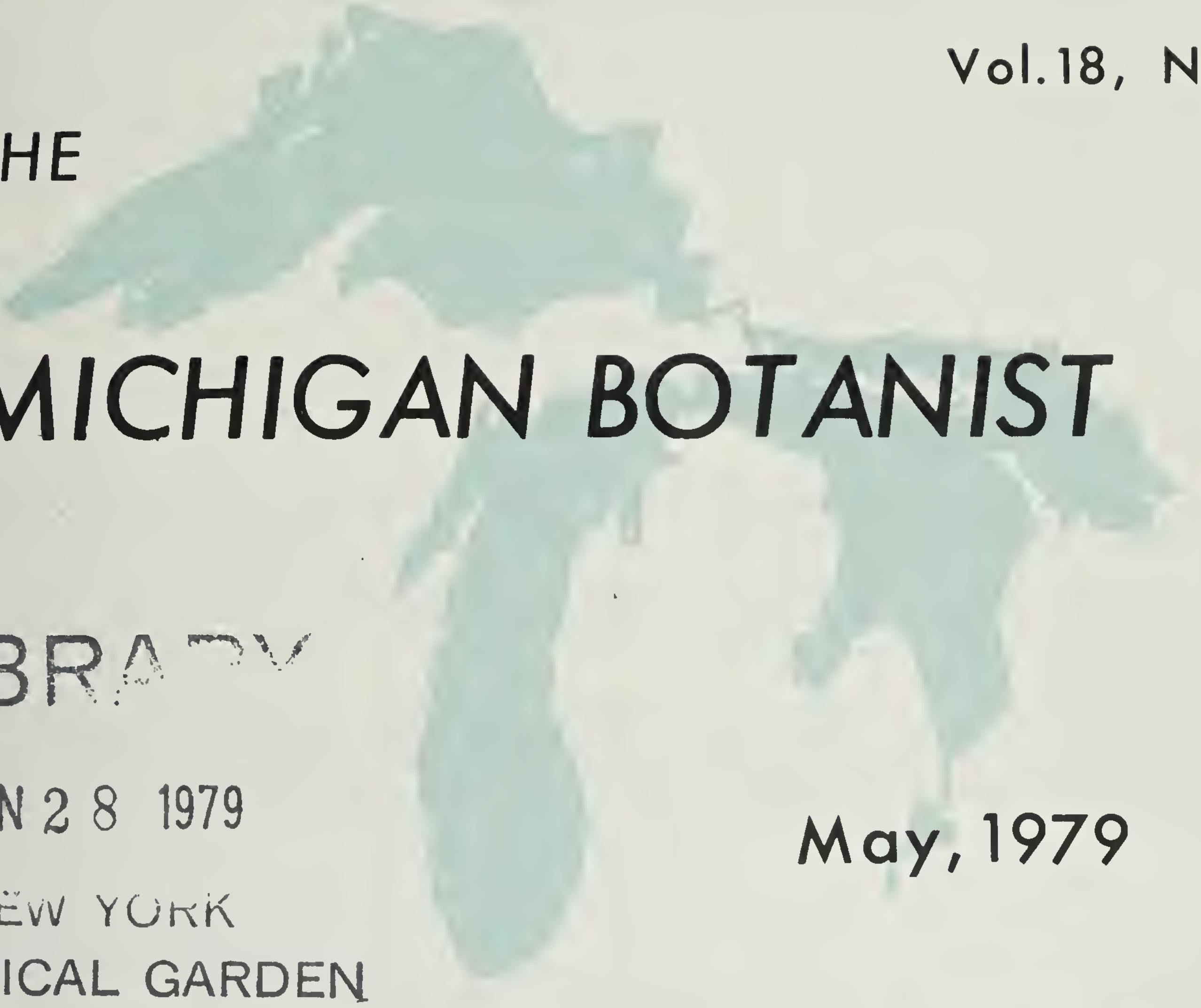
Contributions to Botany by Members of the Michigan Botanical Club
William S. Benninghoff & John H. Beaman 82

The Acceleration of Succession of a Birch-Maple Forest Due to High Wind
Lawrence A. Kapustka & Rudy G. Koch 83

On the cover: Sycamore bark and
the promise of spring; photo by Doug Moore

Vol.18, No.3

THE MICHIGAN BOTANIST



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VEGETATION CHANGES FOLLOWING A WATER LEVEL RISE AND TREE MORTALITY IN A MICHIGAN BOG

Christa R. Schwintzer

Harvard Forest, Petersham, Mass., 01366

Little is known about succession in bogs following water level rises and/or overstory removal. General patterns of change following tree cutting and fire have been described for northern Michigan (Gates, 1942), Minnesota (Conway, 1949) and Wisconsin (Catenhusen, 1950). But there are no complete quantitative descriptions of the ground layer before and after tree removal. Brown (1972) described changes in individual shrub species and sedges as a group in a northern Minnesota bog three years after clear-cutting of trees but did not describe the entire ground layer. And Jeglum (1975) described a low shrub bog that developed in a northern Ontario peatland following tree mortality due to high water levels. The present study examines quantitative changes in the ground layer in a northern Michigan bog known as Bryant's Bog in a five-year period following tree mortality due to elevated water levels.

Bryant's Bog is a small kettle-hole bog in Cheyboygan County, Michigan, and consists of two concentric zones, an outer grounded mat and an inner free floating mat surrounding a central pool (Fig. 1, 2). The peat is acid and nutrient poor. Interstitial waters in the peat have very low Ca and Mg concentrations characteristic of ombrotrophic sites, moderately acid pH values characteristic of weakly minerotrophic sites, and moderate concentrations of N, P, and K (Schwintzer, 1978). Quantitative descriptions of the vegetation and maps of the pool are available for several years. Since 1917 the vegetation changed from open bog dominated by leather-leaf *(Chamaedaphne calyculata)* and *Sphagnum* spp. to treed bog with well-established black spruce *(Picea mariana),* white pine *(Pinus strobus)* and tamarack *(Larix laricina)* trees by the late 1960's, and back to a more open condition as a result of tree mortality during a period of high water in the early 1970's (Schwintzer & Williams, 1974; Schwintzer, 1978). Bryant's Bog has been described in detail elsewhere, and the literature concerning it has also been reviewed (Coburn, *et al.,* 1933; Gates, 1942; Schwintzer & Williams, 1974; Schwintzer, 1978).

The vegetation on the grounded and free mats was sampled with 15 randomly placed nested circular plots in the summers of 1972 and 1977. Trees (over 2.5 cm d.b.h.) were sampled in 25-m^2 plots; and low shrubs, herbs, and bryophytes were sampled in 1-m^2 plots. Bryophytes were divided into two groups, *Sphagnum* spp. and "Other Bryophytes." The 25-m^2 plots were permanently marked and d.b.h. was recorded for each tree in 1975 as well as in 1972 and 1977. The tree layer of 1969 was reconstructed from data on living and recently dead trees obtained in 1972. The 1-m^2 plots were randomly located within the 25-m^2 plots in 1972 and at their centers in 1977. A visual estimate of percent cover was recorded for each vascular species and bryophte group.

Depth to water in the peat was also measured in the vegetation sample plots. Shallow

1

2

wells were dug at the centers of the plots and allowed to equilibrate for approximately 24 hours. Depth to water was then taken as the distance from the peat surface to the water.

Water levels were monitored during the summers from 1972 to 1977 in a well near the southeastern edge of the bog. Water levels were measured as the distance from the water surface to the top of a pipe driven through the peat into the sand beneath. The level at the top of the pipe was assigned an elevation of 100 cm. The pipe stayed securely in place since the elevation of the top of the pipe remained unchanged relative to a cement survey marker on the upland about 10 m away as determined with a surveyor's level in 1972, 1974, and 1977.

Percent frequencies and means and standard deviations of percent cover were calculated for vascular plants and bryophyte groups in the ground layer. Differences between means were tested with a t-test.

Both the grounded and free mats had well-developed stands of trees in 1969 (Table 1), but the grounded mat had only half as many trees as the free mat. Extensive tree mortality occurred in both zones between 1969 and 1972 resulting in the loss of 74% and 54% of the trees on the grounded and free mats, respectively. Some additional mortality occurred between 1972 and 1975 (Table1).

The total cover of the ground layer increased between 1972 and 1977 in both zones, while the number of vascular species present remained essentially unchanged. The increase in cover was primarily due to increases in only a few species (Table 2). Thus on the grounded mat the percent cover of leather-leaf, *Sphagnum* spp., and the Other Bryophytes group increased substantially. *Carex canescens* also appeared to increase but the change was not statistically significant ($P < 0.10$). These increases in cover were accompanied by increases in frequency indicating that these plants increased in the extent of their distribution as well as cover. The frequency of *Sphagnum* spp. reached 100%.

TABLE 1. Densities and basal areas of living trees (d.b.h > 2.5 cm) on the grounded and free mats in Bryant's Bog.

	Grounded Mat		Free Mat	
Year	density trees/ha	basal area m^2/ha	density trees/ha	basal area m^2/ha
1969	1570	19.6	3470	32.8
1972	410	2.6	1620	24.5
1975	130	1.1	1280	20.1
1977	130	1.1	1180	20.2

Fig. 1. Bryant's Bog in 1954. The foreground shows Dr. Frank C. Gates and some of the students in his plant ecology class at The University of Michigan Biological Station mapping the bog. Frank Gates visited this bog with his classes in 1911 and from 1915 to 1954. Note the bog pool in the foreground and vigorous conifers in the background. Photo by David M. Gates. Fig. 2. Bryant's Bog in 1977. Note the bog pool, low shrub zone, and dead conifers in the foreground and background. The trees were killed by high water levels caused by an extended period of unusually wet weather.

TABLE 2. Frequency (1-m^2 plots) and mean cover of selected ground layer plants in Bryant's Bog in 1972 and 1977.[1]

	Grounded Mat				Free Mat			
	Frequency (%)		Cover (%)		Frequency (%)		Cover (%)	
	1972	1977	1972	1977	1972	1977	1972	1977
Carex canescens	7	47	< 1	2	–	–	–	–
C. trisperma	40	73	1	1	80	73	8	8
Chamaedaphne calyculata	47	80	1	18***	73	87	14	25*
Gaylussacia baccata	7	7	< 1	< 1	40	53	5	3
Kalmia polifolia	–	–	–	–	33	33	< 1	< 1
Lycopus uniflorus	80	73	6	1**	33	13	5	1
Nemopanthus mucronata	40	20	< 1	1	7	–	< 1	–
Scirpus cyperinus	33	33	1	< 1	–	–	–	–
Smilacina trifolia	13	13	2	3	40	53	3	10**
Vaccinium angustifolium	27	13	< 1	< 1	60	47	1	1
V. myrtilloides	20	7	< 1	< 1	33	47	< 1	< 1
Sphagnum spp.	87	100	20	50***	100	100	69	90**
Other Bryophytes	53	93	5	21***	80	20	2	< 1*
No. of vascular plants	1972 (15)		1977 (13)		1972 (16)		1977 (17)	
Total cover vascular plants (%)	18		28		36		53	
Total cover bryophtes (%)	25		71		71		91	

---

[1] All plants with frequencies $\geq 33\%$ at one location or time are included. Difference in mean cover significant at $*P < 0.10$, $**P < 0.05$ and $***P < 0.01$.

Most species however remained unchanged while a few decreased in cover. On the grounded mat only water-horehound *(Lycopus uniflorus)* decreased significantly.

Similar changes occurred on the free mat where leather-leaf, *Smilacina trifolia,* and *Sphagnum* spp. increased while the Other Bryophytes group decreased. Water-horehound also appeared to decline in cover and frequency but the change in cover was not statistically significant.

Summer water levels were high in Bryant's Bog from 1972-1976 and declined sharply in 1977 (Table 3A). Depth to water from the peat surface was significantly less in the grounded than the free mat during the period of high water but was approximately the same after the water level declined (Table 3B).

DISCUSSION

The observed ground layer changes probably represent an ongoing response to elevated water and light levels. Major environmental changes occurred between 1969 and 1972, during which period water levels became unusually high due to natural weather patterns (Schwintzer, 1978). The high water levels were accompanied by extensive tree mortality which removed more than half of the overstory (Table 1) and substantially increased light levels in the ground layer.

High water levels increase moisture content and decrease aeration of surface peat. The moisture content of peat increases as depth to water decreases and is rectilinearly correlated with depth to water for water depths from near the surface to 50 cm beneath the surface (Heikurainen *et al.,* 1964). Aeration increases with increasing depth to water and water

TABLE 3. Water levels in Bryant's Bog during the summers 1972-1977 and depth to water on three dates.[1]

A. Water levels (cm)

Year	June		July		August	
1972	—	—	7/20	57	8/12	55
1973	—	—	7/23	49	—	—
1974	6/21	57	7/7	57	—	—
1975	6/23	59	7/14	51	8/18	38
1976	6/23	54	7/20	48	8/16	33
1977	6/23	28	7/22	17	8/11	5

B. Depth to water (cm; Mean ± SD)

Date	Grounded Mat	Free Mat
8/19/75	6.7 ± 4.8	16.3 ± 4.4***
6/25/77	10.5 ± 4.6	15.1 ± 4.3***
8/11/77	25.1 ± 4.4	24.2 ± 5.1

[1] See text for explanation.

***Difference between grounded and free mats significant at $P < 0.01$.

movement (Sparling, 1966). There is little or no lateral water movement in Bryant's Bog because it has no inlets or outlets and is surrounded by sandy upland soils. Under these conditions one would expect anaerobic conditions to prevail within two centimeters of the surface when the peat is completely flooded and throughout the zone beneath the water table when the water table is deeper (Armstong & Boatman, 1967).

Changes in the water table affect depth to water differently in the grounded and free mats (Table 3B) because the grounded mat cannot float up and down with changing water levels, while the free mat can. The ability of free mats with substantial tree growth to rise and fall through distances as great as 75 cm with changing water levels has been well documented (Gates, 1940; Buell & Buell, 1941). Thus during periods of high water, such as that which prevailed from 1969 to early 1977, the depth to water is significantly less in the grounded mat than in the free mat. However, during periods of low water these distances are approximately the same or may even become greater on the grounded mat.

Only a few plants responded substantially to the increased light, increased soil moisture, and decreased thickness of aerobic surface peat accompanying the high water levels. Among the vascular plants leather-leaf showed by far the largest change. It increased substantially in both zones, but the largest increase occurred on the grounded mat which had more tree mortality and a relatively greater increase in light. In addition, there was less competition from previously established leather-leaf and other vascular plants on the grounded mat as indicated by total vascular cover which remained substantially smaller on the grounded mat than on the free one throughout the period of observation (Table 2). The results show that leather-leaf readily tolerates high water. This agrees with observations of Gates (1942) that leather-leaf may spread over sedge mats at the edges of bog pools into open water and Swan & Gill (1970) that it may colonize old stumps in an artificial lake and spread laterally across the water surface to occupy the spaces between stumps.

Carex canescens and *Smilacina trifolia* also increased. *Carex canescens* was found only on the grounded mat where its frequency increased from 7 to 47% accompanied by a small increase in cover. This plant clearly can exploit full sunlight in the presence of high water since it grows at pond or stream margins as well as in bogs (Voss, 1972). In contrast *Smilacina trifolia* was found in both zones but increased only on the free mat where water levels were more moderate.

Water horehound, the only vascular plant that declined significantly between 1972 and 1977, decreased in both zones. This perennial herb may have been more important in the years around 1972 than at any other time in the bog's recorded history. It was not reported in either zone between 1917 and 1955 (Schwintzer & Williams, 1974), and its behavior between 1955 and 1972 is unknown since there are no records for this period. However, large numbers of seedlings were found in 1972 and may represent a rapid response to the increased light levels and other changed conditions accompanying the high water levels. The reasons for the decrease between 1972 and 1977 are not clear but may be related to increasing cover of evergreen plants, primarily leather-leaf and *Sphagnum* spp.

Among the bryophytes *Sphagnum* spp. increased strongly in both zones, its increase in percent cover being almost twice as great as that of leather-leaf. *Sphagnum* growth was probably favored by both the increased light and high water. The Other Bryophytes group decreased on the free mat but increased substantially on the grounded mat. This group was probably also favored by the increased light and high water but was overgrown by rapidly growing *Sphagnum* spp. on the free mat where the cover of *Sphagnum* spp. increased from 69 to 90%. On the grounded mat the final *Sphagnum* spp. cover of 50% left ample room for the more slowly growing Other Bryophytes group. It should be noted that both *Sphagnum* spp. and the Other Bryophytes group are groups of species. Individual species within these groups have their own requirements and tolerances and may be expected to show a range of responses similar to that observed in the vascular species.

The vegetation changes in Bryant's Bog between 1972 and 1977 are similar to changes in a northern Ontario bog following elevation of water levels due to impedence of drainage by a road causeway (Jeglum, 1975) and are also in general agreement with ground layer response to clear-cutting of trees in a northern Minnesota bog (Brown, 1972). In the Ontario bog all trees died on the upslope side of the causeway, and a low shrub bog developed in which eight vascular species including leather-leaf, *Smilacina trifolia*, and *Carex canescens* attained at least 10% cover in one quadrat. Moreover, *Sphagnum* spp. had cover values of 50% or more in most quadrats. In the Minnesota bog leather-leaf, bog laurel *(Kalmia polifolia)*, and *Carex* spp. increased in frequency and cover in a three-year period.

Communities dominated by leather-leaf and *Sphagnum* spp. have been designated as the *Chamaedaphne* association by Gates (1942) and others. This association, one of the most widespread and characteristic of bog associations (Gates, 1942; Conway, 1949; Dansereau & Segadas-Vianna, 1952), varies in species composition across its considerable geographic range in North America (Curtis, 1959). Communities dominated by leather-leaf and *Sphagnum* spp. usually occur at an intermediate stage in primary succession from open water lake to bog forest (Gates, 1942; Conway, 1949; Dansereau & Segadas-Vianna, 1952). They also occur extensively in secondary succession following timber cutting and fires on sites where their members were present before the disturbance (Gates, 1942; Conway, 1949; Catenhusen, 1950). The results of the present study show that they can also develop rapidly from treed bogs following rises in water level, tree mortality caused by reduced substrate aeration, and subsequent increased light.

SUMMARY

Changes in the understory vegetation following a water level rise resulting in extensive tree mortality were examined in two zones in Bryant's Bog. Tree mortality was especially

severe in the outer zone which was located on a grounded mat and had soil water levels very close to the surface. Conditions were more moderate in the inner zone which was located on a free-floating mat. In a five-year period following the bulk of the tree mortality, the understory vascular plants and bryophytes increased substantially in total cover and frequency throughout the bog. Much of the increase in vascular cover was due to leather-leaf which increased considerably in cover and reached a frequency of 80% or more in both zones. Most other vascular plants, however, remained unchanged, whereas water-horehound decreased. Much of the change in total bryophyte cover was due to *Sphagnum* spp. which increased substantially in cover and reached a frequency of 100% in both zones. The results indicate that communities dominated by leather-leaf and *Sphagnum* spp. can develop rapidly from treed bogs, following rises in water levels, tree mortality caused by reduced substrate aeration, and subsequent increased light.

I thank all of the many persons at the University of Michigan Biological Station who have aided this study. Special thanks are due to June M. Dobberpuhl for help in the field and Edward G. Voss for help with plant identification. This work represents a contribution from the University of Michigan Biological Station.

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STUDIES ON TRICHOLOMA VACCINUM AND TRICHOLOMA IMBRICATUM IN NORTH AMERICA

Clark Ovrebo

Department of Botany
Erindale College, University of Toronto
Mississauga, Ontario L5L 1C6

Alexander H. Smith

Herbarium, University of Michigan
Ann Arbor, Michigan 48109

The genus *Tricholoma* (Fr.) Staude is particularly abundant in the coniferous forests and plantations throughout North America. Two common species encountered in these habitats are *Tricholoma imbricatum* (Fr.) Kummer and *Tricholoma vaccinum* (Fr.) Staude. They have similar stature and color and, because they frequently fruit together in the same location, they are often confused by mushroom collectors. In this paper the two species are described, the characteristics used to distinguish them are noted, and the variation within each is discussed.

The general ecological aspects of *T. vaccinum* and *T. imbricatum* are similar. They fruit terrestrially and are believed to form ectomycorrhiza with forest trees. They usually are found near species of *Pinus* and/or *Picea*. Both commonly fruit from late August through October. However, *T. vaccinum* has been collected as early as July in mountainous regions of Colorado and both occur as late as December along the Pacific Coast. As with most fleshy fungi, lack of rain or extensive frosts can alter or prevent their normal fruiting patterns.

The two species have been traditionally distinguished by the degree of scaliness of the pileus surface and by slight differences in the pileus color. The pileus surface of *T. vaccinum* is broken into distinct scales, while the surface of *T. imbricatum* has smaller and fewer scales and is frequently appressed-fibrillose overall. The scaliness can be undeveloped in the button stage of both species. The pileus color of *T. imbricatum* is darker, duller brown as compared to the rusty-brown color of *T. vaccinum* (see observations under *T. vaccinum* for discussion of a lighter variant). Also, the buff ground color is readily apparent between the scales of *T. vaccinum* but to a lesser extent on *T. imbricatum*. In addition, a cortina evident on young buttons of *T. vaccinum* does not occur on *T. imbricatum*. A final character often used to separate the two species is the nature of the stipe context. The stipe of *T. vaccinum* is generally hollow, while that of *T. imbricatum* is solid. This is usually a reliable distinction, but we have occasionally encountered a solid stipe in *T. vaccinum*.

In the descriptions below, color designations enclosed in parentheses are from Ridgway (1912), e.g., Tawny; Kornerup & Wanscher (1967), e.g., 6E5; Kelly (1965), e.g., 55 Strong Brown; Munsell (1976), e.g., 7.5YR 3/6. Macroscopic color reactions were tested with aqueous 3% KOH; PDAB (p-dimethyl aminobenzaldehyde—2g, 95% ethanol—76 ml, conc. HCl—24 ml); and aqueous 10% $FeSO_4$. Microscopic features were observed in 3% KOH and Melzer's reagent. Collections with Ovrebo and Tanghe numbers are deposited in the Erindale College Herbarium (TRTE), those with Malloch numbers in the University of Toronto Herbarium (TRTC), those with Smith and Harrison numbers in the University of Michigan Herbarium (MICH), those with Tylutki numbers in the University of Idaho Herbarium (ID).

Tricholoma vaccinum (Fr.) Staude, Die Schwämme Mitteldeutschl. 128.1858. FIGS. 1-4.

PILEUS 20-70 mm broad, when young obtuse, obtusely conic or convex, when mature expanding to convex, broadly convex, broadly rounded conic or more or less plane, often with a rounded or slightly acute umbo; margin incurved when young, when mature cottony on edge or with appendiculate flaps of fibrils soon after separation from the stipe, finally straight and rarely appendiculate; dry; when young fibrillose overall or with occasional scattered squamules, when mature densely matted fibrillose or rimose-areolate on the disc, the rest of the pileus having a combination of appressed or recurved fibrils, squamules, or scales, occasionally rimose-areolate nearly overall; medium rusty tan or rusty brown (55 Strong Brown, Tawny, Hazel, Ochraceous Tawny) overall, the disc often darker brown (Verona Brown, Cinnamon Brown, 7.5YR 3/6) or sometimes overall, occasionally light tan or cinnamon (Cinnamon, Pinkish Cinnamon, 5YR 6/8) overall, the color being contained on the fibrils, squamules or scales, the buff ground color generally exposed between the vestitures; context 5-7 mm thick, buff, often light brown below the cuticle or watery gray above the lamellae; odor and taste nondescript to farinaceous.

LAMELLAE 2-8 mm broad, arcuate when young, when mature emarginate to sinuate, rarely adnate or subdecurrent; whitish buff, becoming very light cinnamon overall in extreme age, discoloring yellowish brown (Ochraceous Tawny, 6C5-6D5) on edge and/or in spots on the face; entire; close; lamellulae numerous but not arranged in distinct tiers.

STIPE 30-80 mm long, 6-22 mm thick, equal or occasionally clavate or obclavate, the base rounded or abruptly tapered; dry; silky fibrillose, often roughened with loosened surface fibrils, with recurved squamules present or not, the apex often pruinose; when young light buff overall or with brown squamules against a buff ground color, when mature light buff at the apex, the lower portion either with brown squamules or if squamules absent, becoming evenly or unevenly brownish buff to rusty brown, often watery brown at the base; context light buff, frequently watery grayish brown when mature, hollow or rarely solid.

VEIL a cortina of light brown fibrils; remnants present in the form of fugacious fibrillose flaps on the pileus edge, no traces remaining on the stipe.

CHEMICAL COLOR REACTIONS: $FeSO_4$ grayish at stipe base and olive gray on the pileus cuticle, KOH and PDAB no reaction.

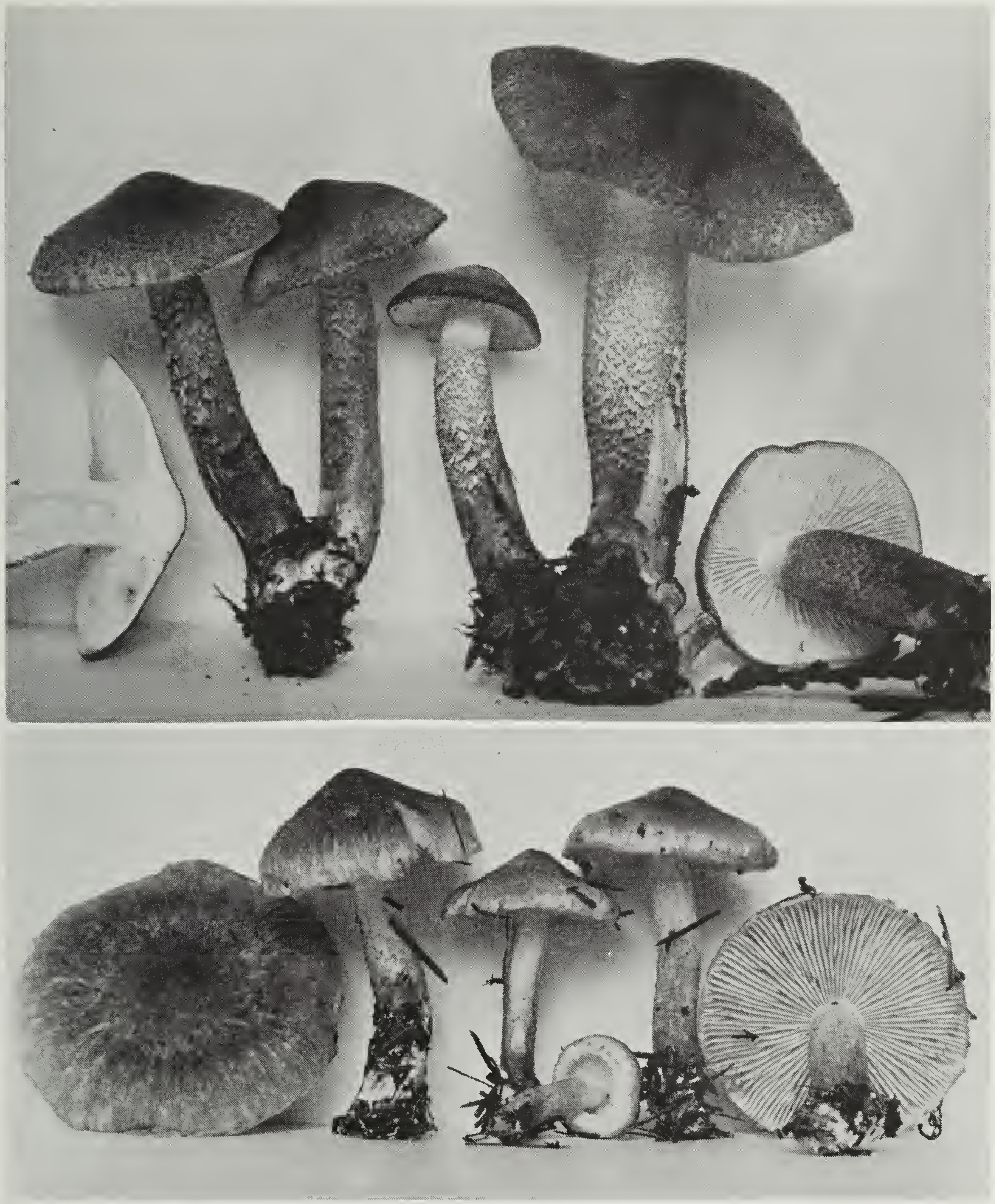

Fig. 1-2. *Tricholoma vaccinum*. 1(above), ⅔ natural size (Smith 8129). 2(below), ⅔ natural size (Smith 56374).

SPORES white in mass when fresh, 6.2-7.6 × 4.2-4.8 μm, elliptic in profile and face view, appearing slightly obovate if not in perfect profile, smooth, thin-walled, hyaline, inamyloid. BASIDIA 30-38 × 6.7-7.6 μm, 4-spored, clavate, hyaline or light yellowish brown, inamyloid. HYMENIAL CYSTIDIA absent. CAULOCYSTIDIA recurved hyphal end-cells at the stipe apex, 29-38(−95) × 2.9-5.7 μm, filamentous, cylindric, cylindro-flexuous or strangulated, smooth, thin-walled, clear, single or in

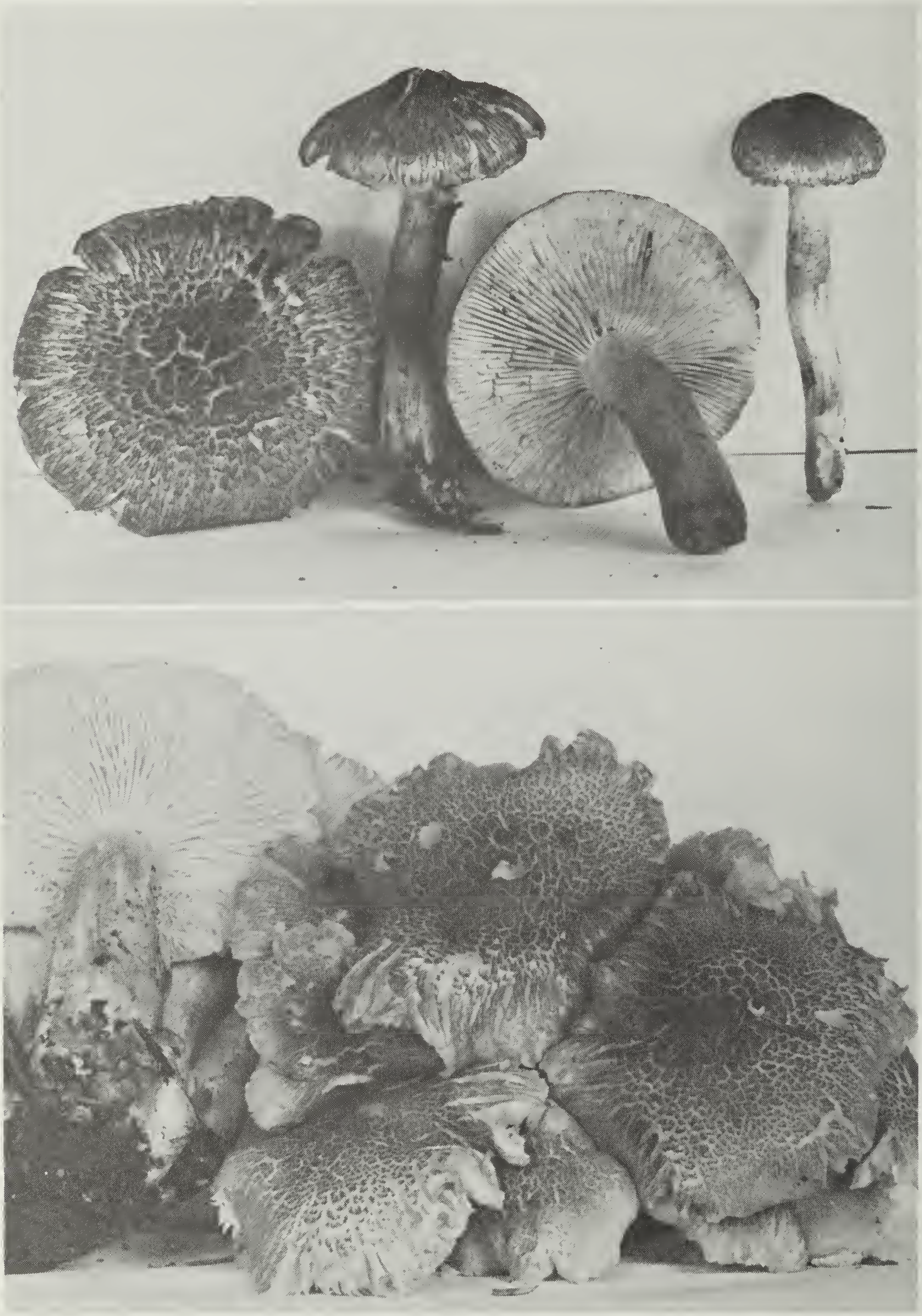

Fig. 3-4. *Tricholoma vaccinum*. 3(above), slightly less than natural size (Ovrebo 816). 4(below), ½ natural size (Smith 69972).

fascicles, hyaline, inamyloid. TRAMAL HYPHAE OF LAMELLAE 2.9-14 μm broad, parallel, cylindric to slightly inflated, hyaline, inamyloid. HYPHAE OF SUBHYMENIUM 1.9-2.9 μm broad, hyaline inamyloid. HYPHAE OF PILEUS CUTICLE 2.9-14 μm broad, interwoven at the disc, elsewhere radially appressed to radially interwoven and often agglutinated into recurved fascicles, cylindric to slightly inflated, smooth and thin-walled or roughened and thickened with hyaline incrustations, yellowish brown to rusty brown, inamyloid. HYPHAE OF PILEUS TRAMA 2.9-14 μm broad, interwoven at the disc, radially arranged elsewhere, narrowly cylindric near the cuticle, cylindric to slightly inflated elsewhere, the walls slightly refractive, hyaline, inamyloid. HYPHAE OF STIPE SURFACE 3.8-12.4 μm broad, longitudinally appressed or forming recurved fascicles, cylindric, smooth and thin-walled or slightly roughened and thickened with hyaline incrustations, hyaline or yellowish brown, inamyloid. HYPHAE OF STIPE TRAMA 3.8-14 μm broad, parallel, compacted, cylindric, hyaline to light brown, inamyloid. HYPHAE OF CORTINA 4.8-15 μm broad, cylindric to slightly inflated, smooth, thin-walled, hyaline or very light brown in mass, inamyloid. HYPHAE AT STIPE BASE 2.9-4.8 μm broad, smooth, thin-walled, hyaline, inamyloid. OLEIFEROUS HYPHAE hyaline to light yellow, inamyloid. CLAMP CONNECTIONS absent.

Gregarious or caespitose under species of *Pinus* and/or *Picea,* July to December.

EDIBILITY: Not recommended.

COLLECTIONS EXAMINED: CANADA: Nova Scotia: Harrison 8286; Ontario: Malloch 7-9-73/4[1], 6-10-74/1, 6-10-74/3, 29-8-78/6, Ovrebo 526, 773, 791, 816, 874. UNITED STATES: California: Smith 56374, 56619; Colorado: Smith 87378, 87654, 88760, 88097, 88098; Idaho: Smith 60238, 69972, Tylutki 2015; Michigan: Smith 67772; Minnesota: Ovrebo 492; New York: Tanghe 10-30-76/9, 10-9-77/7, 10-15-77/A-4; Oregon: Smith 8129, Tylutki 4206, 4400.

A comparison to *T. imbricatum,* the most closely related species, is given in the introduction. In addition, *T. vaccinum* itself varies in respect to pileus and stipe surface features and in pileus color.

The pileus surface exhibits variation in the type of scales present. In the typical and most common variant, the pileus cuticle breaks into diffracted scales and squamules, generally exposing the light buff ground color (Fig. 3). These scales can be appressed or recurved and are oriented in radial fashion. The young pilei are usually fibrillose and lack the larger scales found on mature pilei. As the pilei expand the scales develop. In some collections the surface does not become diffracted scaly. Instead, a rimose-areolate surface results (Fig. 4). This condition does not necessarily cover the entire surface as a few squamules or scales may be present on the pileus edge. Another variant, not clearly of the above types, is squamulose-scaly, but there are fewer scales and they are less well defined (Fig. 2). In all of the above variants appressed or recurved surface fibrils are also present. In the last variant they are the most prevalent form of surface vestiture.

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[1] Malloch collections number are given as day-mo-yr/coll. no., Tanghe numbers as mo-day-yr/coll. no.

The pileus color in *T. vaccinum* is most commonly medium rusty brown. Often the disc is darker than the margin. Associated with the last variant above (least scaly one) and rarely with the others is a lighter pileus color. In this case the fibrils or scales are a lighter brown: light tan or pinkish cinnamon to cinnamon colored.

The stipe surface is most frequently silky fibrillose and often slightly roughened with torn surface fibrils (Fig. 2). In comparison, the stipe is often covered with small squamules (Fig. 1). Collections may possess stipes with only one of these states, or there may be a combination of both. The squamulose stipe appears to be restricted to carpophores with the rusty brown pileus.

It is difficult to propose reasonable explanations that account for the variability observed in *T. vaccinum.* It may be a combination of environmental and genetic factors. The variants clearly belong to the same species, and at this time they do not appear to deserve varietal status. The most recent and comprehensive account of the species is given by Bon (1969; 1976), who recognizes two varieties: var. *vaccinum,* which corresponds most closely to the typical rusty brown, diffracted scaly form discussed here, and var. *fulvosquamosum* Bon, which is characterized by a "lepiotoid" arrangement of the squamules on the pileus surface. The latter variety does not correspond to any of our variants and is not known for certain to occur in North America.

Tricholoma imbricatum (Fr.) Kummer, Der Führer in die Pilzkunde 133. 1871. FIG. 5.

PILEUS 20-100 mm broad, when young obtuse, obtusely conic or convex-umbonate, when mature expanding to obtusely conic, convex, broadly convex or convex-umbonate; margin incurved to inrolled when young, when mature slightly incurved to straight, often wavy; dry; densely matted-fibrillose or rarely naked on the disc, appressed fibrillose to appressed or slightly recurved squamulose elsewhere, the extreme margin occasionally striate and rarely naked; when young light dull brown (Cinnamon Brown) on the disc and light buff on the margin, when mature dark dull brown (6E4, 6F8, Bister, Chestnut Brown, Warm Sepia) overall or lighter on the edge; context 5-10 mm thick, white, pale buff, often light brown near the cuticle and watery gray above the lamellae; odor absent and taste absent to slightly acrid.

LAMELLAE 2-7 mm broad, arcuate on buttons, emarginate to sinuate when mature; whitish buff, discoloring light yellowish brown to dull brown in spots or more or less diffused; entire; close; lamellulae numerous but not arranged in distinct tiers.

STIPE 35-60 mm long, 5-15 mm thick, equal, ventricose or obcla-

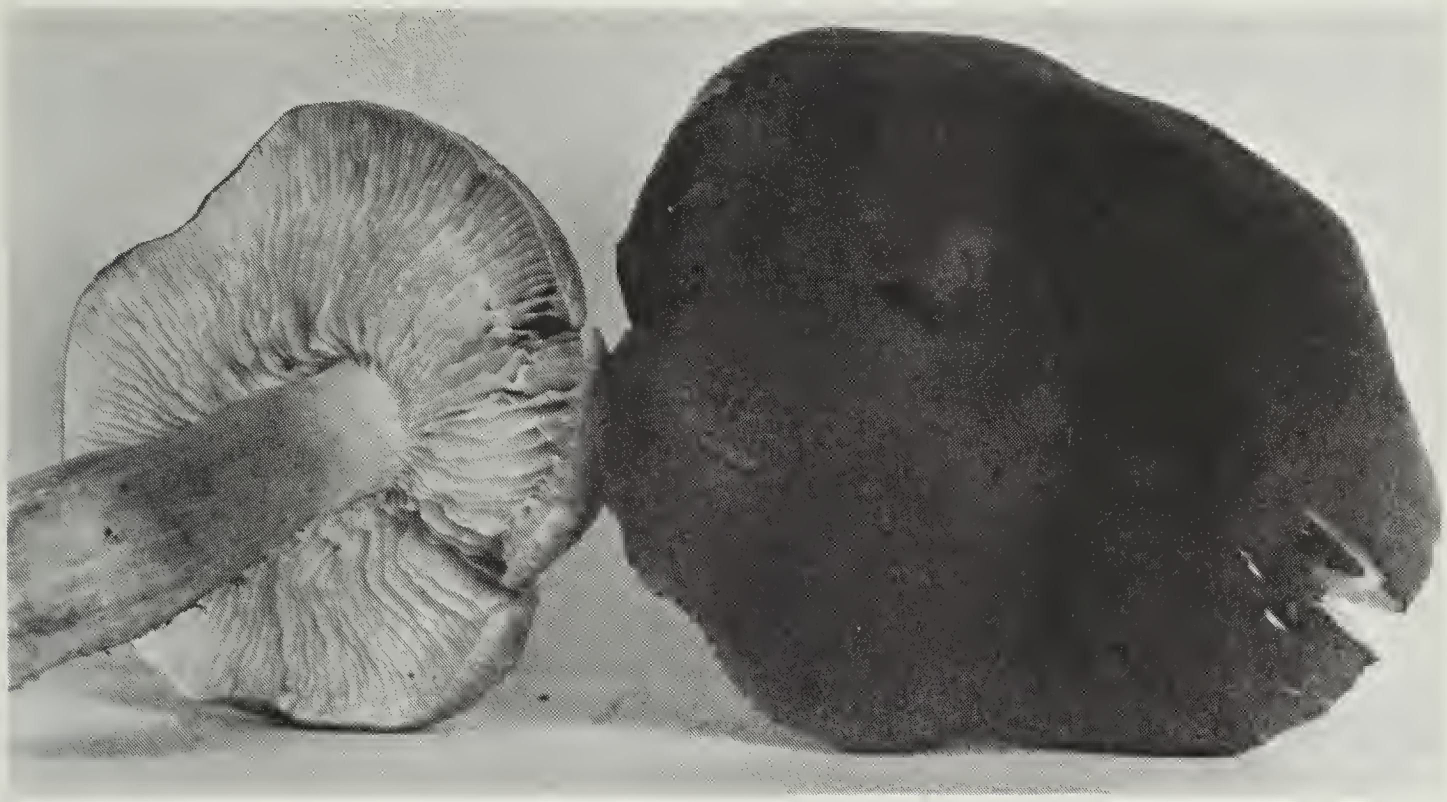

Fig. 5. *Tricholoma imbricatum,* ½ natural size (Smith 77041).

vate, the base abruptly tapered; silky fibrillose and with loosened surface fibrils, slightly pruinose at the apex; buff overall when young, when mature the apex remaining so but darkening to dark buff or light brown (Cinnamon Brown) over the lower portion, often watery brown at the base, occasionally discoloring watery brown or yellowish buff in spots; context buff overall or often yellowish brown or watery brown at the base, solid.

CHEMICAL COLOR REACTIONS: KOH and PDAB no reaction.

SPORES white in mass, 5.7-6.7 × 4.2-4.8 μm, broadly elliptic in profile and face view, smooth, thin-walled, hyaline, inamyloid. BASIDIA 27-34 × 6.7-7.6 μm, 4− or rarely 2-spored, clavate, hyaline, inamyloid. HYMENIAL CYSTIDIA absent. CAULOCYSTIDIA recurved hyphal end-cells at stipe apex, 27-55 (−76) × 2.7-8.6 μm, cylindric, cylindro-flexuous or strangulated, smooth, thin-walled, in fascicles or as a turf, clear or often translucent, hyaline, yellowish brown or brown, inamyloid. TRAMAL HYPHAE OF LAMELLAE 2.9-11 μm broad, parallel, cylindric to slightly inflated, hyaline, inamyloid. HYPHAE OF SUBHYMENIUM ± 2.9 μm broad, hyaline, inamyloid. HYPHAE OF PILEUS CUTICLE 3.8-9.5 μm broad, interwoven at the disc, radially appressed elsewhere, cylindric, smooth and thin-walled or roughened and thickened with hyaline incrustations, light reddish brown to rusty brown with the outermost hyphae of the cuticle darkest, inamyloid. HYPHAE OF PILEUS TRAMA 3.8-13 μm broad, interwoven at the disc, ± radially arranged toward the margin, narrowly cylindric to slightly inflated elsewhere, walls slightly refractive, hyaline, inamyloid. HYPHAE OF STIPE SURFACE 1.9-6.9 μm broad, longitudinally appressed to slightly interwoven, cylindric, smooth, thin-walled or slightly roughened, light yellowish brown to rusty brown, inamyloid. HYPHAE OF STIPE TRAMA

2.9-11.4 μm broad, parallel, compacted, cylindric to slightly inflated, hyaline, inamyloid. HYPHAE AT STIPE BASE 1.9-4.8 μm broad, cylindric, smooth, thin-walled, hyaline, inamyloid. OLEIFEROUS HYPHAE hyaline to light yellowish brown, inamyloid. CLAMP CONNECTIONS absent.

Solitary, gregarious or caespitose under species of *Pinus* and/or *Picea*, September to December.

EDIBILITY: reported as being edible.

COLLECTIONS EXAMINED: CANADA: Ontario: Ovrebo 486, 524, 768. UNITED STATES: Idaho: Smith 70959, 77041; Michigan: Ovrebo 424, 746, 756, Smith 67787.

Tricholoma inbricatum exhibits little variation as compared to *T. vaccinum*. It is less common than *T. vaccinum,* and the basidiocarps typically are more robust and more often than not solitary to scattered.

We thank Leo Tanghe, Rochester, New York, and Edmund E. Tylutki, University of Idaho, for the loan of collections. Portions of this study were financed by National Research Council grant (A9861) to Joseph F. Ammirati.

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STROPHARIA RIPARIA, A PREVIOUSLY UNDESCRIBED SPECIES SUSPECTED OF OCCURRING IN MICHIGAN

Alexander H. Smith

Herbarium, University of Michigan, Ann Arbor, 48109

Stropharia riparia sp. nov. Fig. 1

Pileus 3-9 cm latus, obtuse umbonatus demum late umbonatus vel late convexus, glaber sed ad marginem appendiculatus, pallide luteus demum luteo-olivaceus vel olivaceus, subviscidus; sapor mitis. Lamellae late adnatae demum adnexae, confertae, luteolae dein violaceo-brunneae. Stipes 6-9 cm longus, 4-12 mm crassus, aequalis vel subaequalis, pallidus, deorsum demum brunneus, sursum glaber, deorsum fibrillosus vel subsquamulosus; annulus submembranaceus, evanescens, pallidus. Sporae 11-15 × 6-8 μm. Pleurocystidia nulla. Cheilocystidia subfilamentosa, 30-40 × 4-5 μm. Specimen typicum in Herb. Univ. Mich. conservatum est; legit prope La Push, Washington, May 19, 1939, A. H. Smith no.13606.

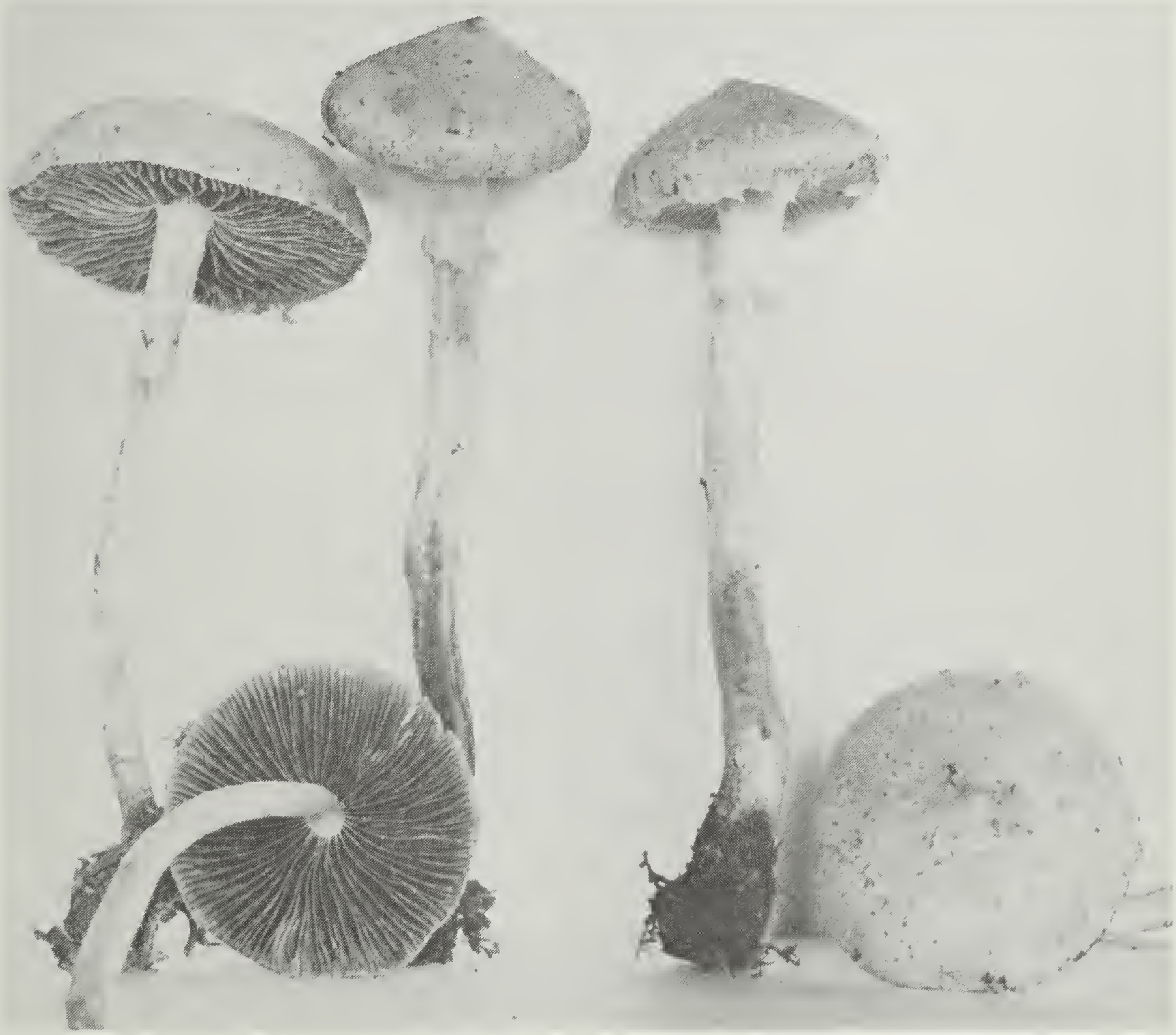

Fig. 1. *Stropharia riparia* Smith ×1 (*Smith* 3170).

Pileus 3×9 cm broad, obtusely umbonate to convex when young, the margin slightly incurved at first, in age broadly convex, plane or with an elevated margin, when young with inconspicuous fibrillose scales near the margin, margin appendiculate with submembranous patches of the veil at first, viscid to sub-viscid, color "cream buff" on the disc and "cartridge buff" toward the margin in young specimens (pale-yellow with a slightly darker disc), slowly becoming "Isabella color" to olivaceous in aging, at times the disc becoming tinged orange. Context firm, whitish, 3-4 mm thick in the disc, tapered to margin, soft, odor and taste mild.

Lamellae broadly adnate and usually toothed, becoming depressed around the stipe at maturity, close, broad (5-7 mm), "ivory yellow" (whitish) young, soon "Benzo brown" (violaceous brown), edges even.

Stipe 6-9(12) cm long, 4-10(12) mm thick, equal or slightly enlarged above or below, hollow, white or whitish (pallid) but in age sordid-brownish near the base, somewhat fibrillose to subscaly below the annulus, glabrous above; annulus submembranous or merely fibrillose, whitish, usually very ragged and soon vanishing.

Spores 11-14(15) × 6-8 μm, elliptic to subovate in face view, smooth, dark yellowish-brown in KOH, truncate from a hyaline apical to subapical pore. Basidia four-spored, 28-34 × 8-9 μm, hyaline in KOH. Pleurocystidia none. Cheilocystidia abundant and forming a sterile band on the gill edge, 20-40 × 4-7 μm, hyaline in KOH, clavate when young but soon filamentose and flexuous. Gill trama of interwoven hyphae 6-12 μm diam, hyaline in KOH; subhymenium cellular at maturity. Cuticle of pileus a thin ixocutis; clamps present.

HABIT AND HABITAT. Solitary to gregarious or subcespitose on soil under alder and species of *Populus* (cottonwood and small-toothed aspen), in moist places such as seepage areas and along streams, spring and fall, common in the aspen forests of the Rocky Mountains, and under cottonwood and alder in the Pacific Northwest (reported by Smith, 1941, as *Stropharia magnivelaris* Pk.).

This species is presented here because I desire to obtain collections from Michigan. To my knowledge it has not been found in the state as yet, but our forests of aspen are extensive, and I suspect it has been found here but not identified. Its pattern of distribution appears to coincide with that of both *Russula aeruginea* Lindbl. *ex* Fr. and *Lactarius controversus* (Fr) Fr., two European species which occur in the same habitats as *S. riparia* here in Michigan and in our western area. On the basis of circumstantial evidence it may be concluded that all three form mycorrhiza with species of *Populus* in North America.

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FLOWER BIOLOGY AND ARTHROPOD ASSOCIATES OF LILIUM PHILADELPHICUM

Edward M. Barrows

Dept. of Biology
Georgetown University
Washington, D.C., 20057

Flowers of *Lilium philadelphicum* bear pollen mostly during the first day of bloom and nectar on an irregular schedule during the first six days of anthesis. Pollination experiments suggest that this species must cross-pollinate to produce seeds. Butterflies which transfer pollen of this lily with their wings and pollinating sweat bees show "suboptimal" foraging movements on individual flowers. Mirid bugs, ants, and other butterflies steal nectar. Tortricid larvae consume flower parts.

The wood lily, *Lilium philadelphicum,* occurs mainly in southern Canada and the northern quarter of the United States; its large, upright flowers have tepals that vary from faded orange to deep orange-red and scarlet or to yellow (Fernald, 1950). This paper concerns arthropod associates and behavior of these flowers which are subjects that are basically unstudied in the genus *Lilium* as a whole.

Lilium philadelphicum was studied on the property of the University of Michigan Biological Station, Cheboygan County, Michigan, from mid-June to mid-July 1977 and 1978. Hundreds of plants grew in a marshy area which was cleared for an oil pipeline which was laid down in 1953. Plants that were studied had from one to five flowers with tepals ranging from light orange to near scarlet to yellow (forma *flaviflorum* E. F. Williams). One plant had orange tepals without the usual purple spots. Unbagged, individual flowers were tagged before they opened and examined on about every day until 10 days after anthesis. Manostat dial calipers (accurate to 0.05 mm) were used to measure pistil and stamen lengths (distances from upper sides of tepal bases to tips of pistils and stamens). Net bags with 1 × 1 mm holes were used to exclude pollinators. Bagged flowers were artificially crossed or selfed by touching their stigmas with appropriate anthers. Pollen was lighter in color than stigmas; thus, its presence on them was easily seen. Forceps which held anthers during pollination experiments were washed well in 70% ethanol between pollination attempts. Means, standard deviations, and sample sizes are given in parentheses after ranges.

Flowers of *L. philadelphicum* are among the largest in their habitat. Blossoms were from 8.3 to 11.8 cm in diameter (10.06, 1.026, 20); pistils, from 53.73 to 69.75 mm long (61.729, 4.0957, 17); stamens, from 51.26 to 75.16 mm long (64.071, 5.7620, 17); and anthers from 7.09 to 13.26 mm long (10.842, 1.6916, 17). In 35% of 17 flowers, anthers extended proximally and distally with respect to stigmas but did not touch them.

Events of anthesis are given in Table 1. Flowers opened in mid-morning (about 0900) and, by the afternoon on bright, warm days, 1-day flowers totally opened their anthers. Neither Graenicher (1907) nor I detected a fragrance in these lilies. Tepals of opened flowers were not seen to close in the evening in the field or at any time of the day in 20 cut flowers in water. Anthers of 3-day flowers were shriveled and contained little or no pollen. Nectar was seen as droplets on the bases of outer tepals in low

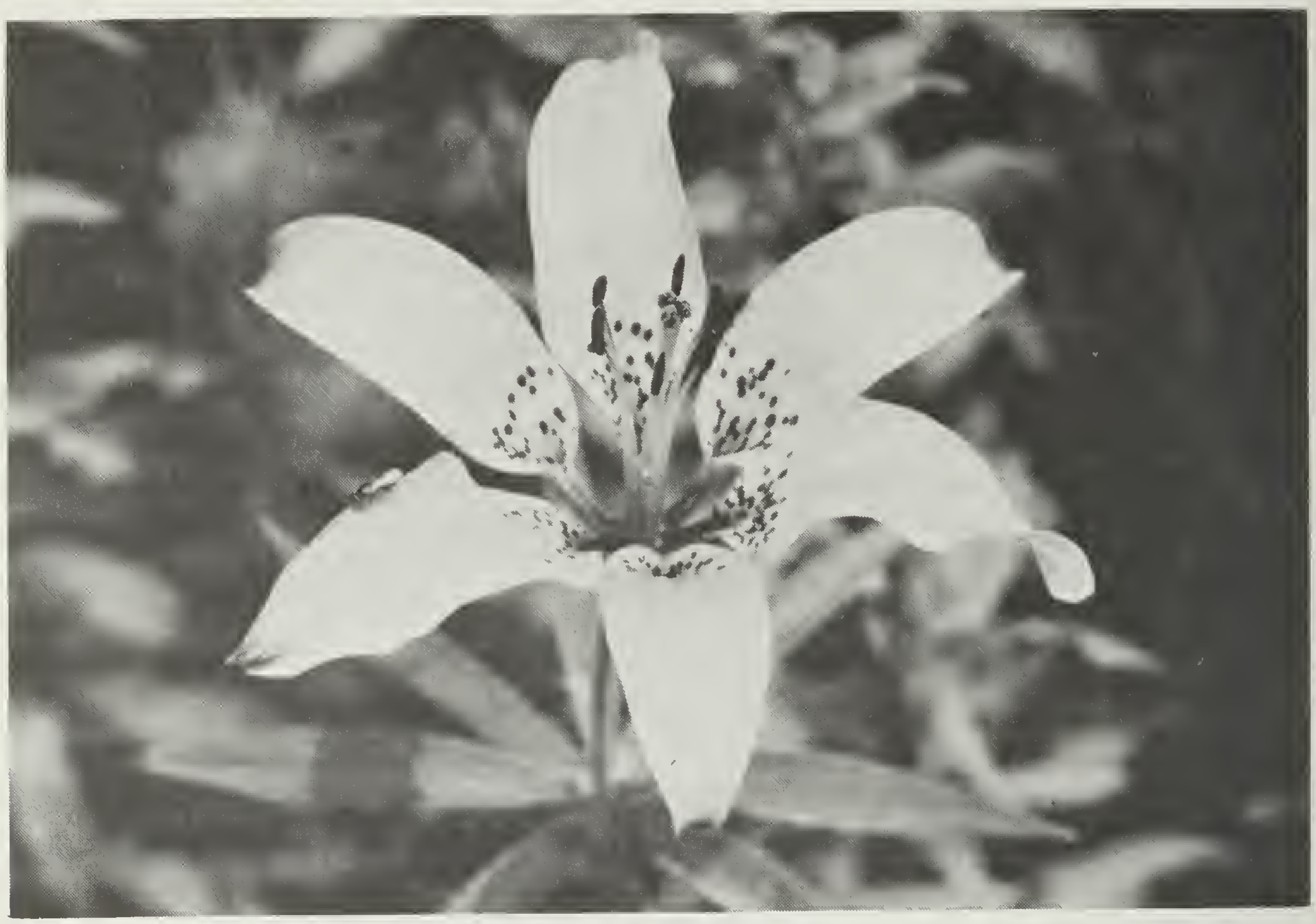

Fig. 1. A *Dialictus* sp. on a flower of *Lilium philadelphicum*.

percentages of 1-, 2-, 3-, 4-, and 6-day flowers. Five-day flowers were not observed because of rain. Particular flowers did not provide nectar droplets in any regular temporal sequence; therefore, nectar occurred unpredictably among flowers from the standpoint of pollinators and other nectar foragers. This nectar-producing strategy may increase cross-pollination while conserving energy for these lilies which appreciably invest in large, colorful flowers with much pollen. Twenty-one 10-day ''flowers'' no longer bore tepals or stamens; small, firm, green capsules were present.

Seventeen flowers were bagged in pollination experiments; nine were artificially cross-pollinated; and eight were self-pollinated. Eight of the plants used in this experiment disappeared, were gnawed off at their bases, or were chewed into pieces possibly by raccoons or muskrats. Of the remaining nine plants, the four cross-pollinated ones had firm, green capsules, and the five self-pollinated ones had yellowish, soft capsules at three weeks after artificial pollination attempts. This suggests that *L. philadelphicum* relies on cross-pollination for seed production as does *L. canadense* (Meehan, 1875) and other lilies (Müller, 1883, p. 556; Davis, 1956).

Sweat bees, *Dialictus* spp. including *Dialictus cressonii* (Halictidae), often visited lily flowers in late morning and early afternoon. These bees are relatively small compared to the lily flowers (Fig. 1). They frequently crawled over and deposited pollen on stigmas as they moved among flowers. Movements of a *Dialictus* on a *Lilium* flower are shown in Fig. 2.

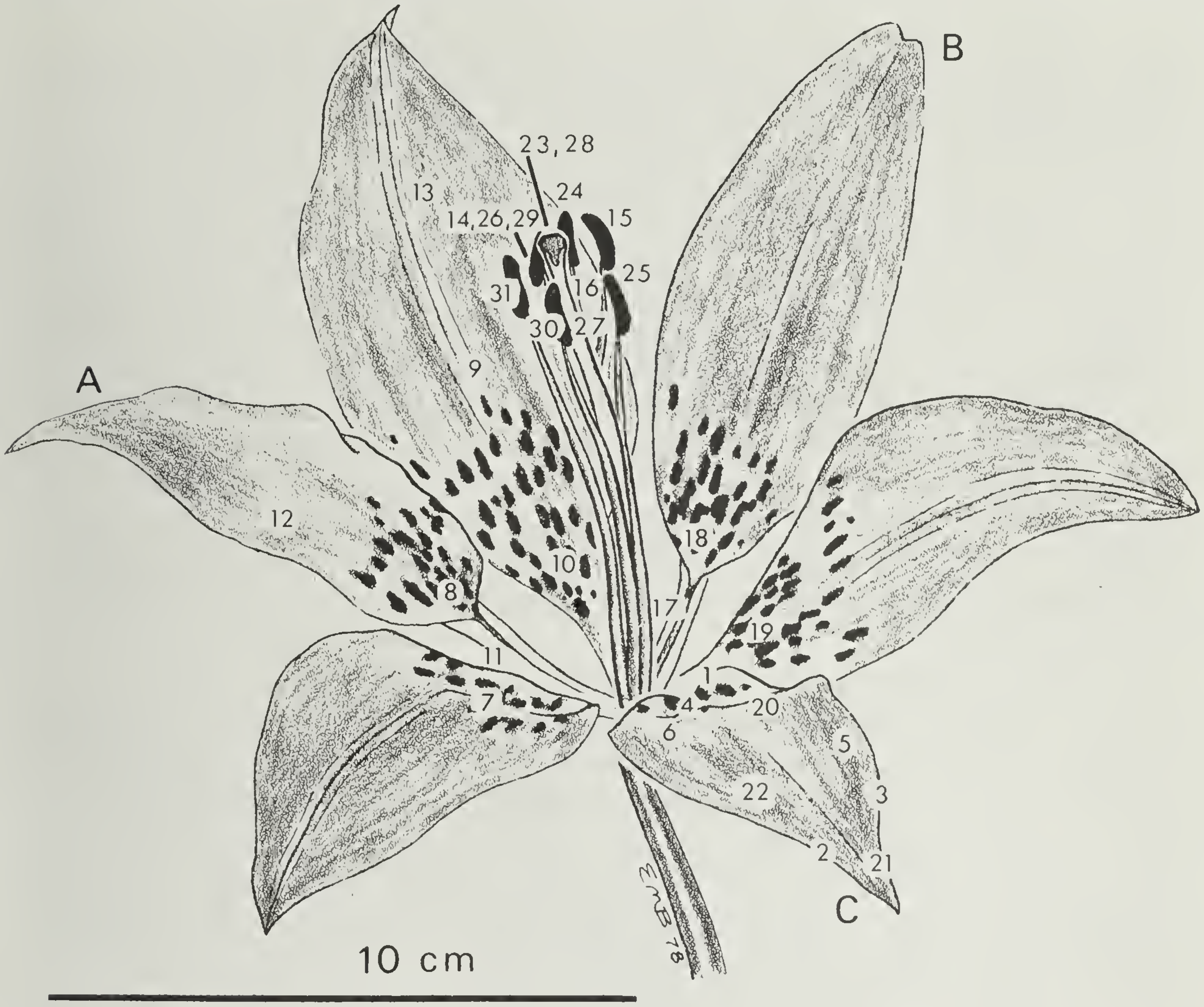

Fig. 2. Movements of a *Dialictus* sp. on a flower of *Lilium philadelphicum* in 167 sec. The bee landed in area 1, crawled to 2, 3, 4, etc. From area 22, she flew to 23, crawled to 24, 25, etc., and was captured when she flew from area 31. Nectaries are at the bases of tepals A, B, and C. Nectar droplets occurred in A and B, and the anthers and the stigma bore pollen. The bee collected nectar while she was in areas 11 and 17.

Six sweat bees (that were captured and killed for identification purposes) showed behaviors that reduced their efficiencies in foraging on individual lily flowers. Each bee displayed one or more behaviors: (1) flew or crawled to depleted anthers or nectaries without obvious droplets of nectar, (2) crawled on stigmas, (3) collected pollen externally before imbibing nectar or eating pollen, (4) alternated pollen and nectar collecting more than once, (5) did not move directly from one anther or nectary to the next, and (6) in breezes, lost "footing" and crawled extra distances on filaments and styles. The bees apparently did not sense the states of anthers and nectaries from a distance of even a few centimeters because they visited essentially depleted nectaries and anthers. They crawled on depleted anthers as if searching for pollen and licked at depleted nectaries as if searching for nectar. Whether a bee crawls or flies among food sources is related to its energy budget. Energetics of foraging have been studied in, e.g., bumble bees (Heinrich, 1977) but not in sweat bees. In the short term, it seems inefficient for a bee to visit a lily stigma, although in the longterm, the bee's pollination activity results in food for future relatives. These bees did not appear to take nutritive material from stigmas. Regarding (3), it would seem more efficient for a bee to imbibe nectar and eat pollen first and collect pollen in her scopae second. This would reduce the cost of carrying a pollen load while feeding. Moreover, collected pollen is less likely to fall off when bees reduce the time during which they carry it. The bees usually did not take the shortest crawl or flight paths among anthers and nectaries, so they may not have learned the spatial locations of these resources. Finally, these bees have not evolved structures that enable them to cling to slippery lily parts during breezes. Eight similar observations were made on bees which I did not capture.

Thus, these bees are constrained in being as efficient (optimizing) in obtaining food as a theoretical biologist could imagine them to be. Constraints on biological optimization are universal (Oster & Wilson, 1978, Chapter 8). However, these bees can be expected to make a net energy gain with regard to the time and energy which they expend in foraging (Schoener, 1971).

Five tiger swallowtail butterflies *(Papilio glaucus,* one male and four females) and one female monarch *(Danaus plexippus)* were closely observed on the lilies. Butterflies crawled inside them, and each of four probed with its proboscis the same nectary of a particular flower more than once. The butterflies also probed tepal bases without nectaries. Thus individual butterflies do not avoid nectaries which they previously visited and like the bees do not show optimal foraging. Pollen was obvious on the front marginal areas of the undersides of butterfly forewings. These butterflies commonly move from flower to flower and, twice, I saw them deposit pollen on stigmas with their wings. Graenicher (1907) reported that *Speyeria cybele* also pollinates *Lilium philadelphicum* (= *L. umbellatum)* by transfer of pollen with wings, and Davis (1956) reported that *Papilio* sp. pollinates *Lilium humboldtii* with its hindwings.

Larvae of *Archips negundanus* Dyar, *Choristaneura rosaceana* (Harris), and *Sparanothis reticulatana* (Clemens), Tortricidae, ate stigmas, stamens, and tepals of *L. philadelphicum.* Thomisid spiders *Misumena vatia* (Clerk) in yellow phases captured *Papilio glaucus* which visited the flowers. Several ruby-throated hummingbirds flying in the marsh were not observed to visit the lilies. Nectar robbers, nectar foragers, pollen foragers, and pollinators of North American *Lilium* are listed in Table 2. (A nectar robber is an animal which takes nectar from a flower without pollinating it. From the literature, it is not always clear if nectar, pollen, or both foragers are also pollinators of particular lilies).

Lilium flowers appear to have co-evolved with hummingbird and medium to large lepidopteran pollinators. Davis (1956) listed some general reasons for this hypothesis: (1) nectar grooves are comparable in length to the tongues of these animals; (2) nectar is usually inaccessible to short-tongued insects; (3) distances between the stigmas and nectaries indicate that small insects would not pollinate while imbibing nectar; (4) distances between stigmas and anthers indicate that small insects would not pollinate while being on an anther from which they are taking pollen; and (5)

TABLE 1. Floral change in *Lilium philadelphicum.*

	Morning (%, no. flowers)[a]	Afternoon (%, no. flowers)
Day 1		
Anthers:		
closed	89(52)	0(46)
open	11(52)	4(46)
reflexed	0(52)	96(46)
Stigma with pollen	6(47)	96(46)
Nectar droplets present	2(47)	0(46)
Day 2		
Anthers:		
closed	53(32)	0(49)
open	47(32)	0(49)
reflexed[b]	0(32)	100(49)
Nectar droplets present	0(32)	8(49)
Day 3		
Anthers:		
shriveled[b]	15(13)	15(13)
Nectar droplets present	0(13)	8(13)
Day 4		
Anthers:		
shriveled[b]	7(41)	37(43)
Nectar droplets present	27(41)	26(43)
Day 5		
Anthers:		
shriveled[b]	25(32)	50(40)
Nectar droplets present	rain[c]	rain
Day 6		
Anthers:		
shriveled[b]	57(42)	78(46)
Nectar droplets present	9(42)	7(42)
Day 7		
Anthers:		
shriveled[b]	76(37)	0(37)
Nectar droplets present	rain	0(36)
Day 10		
Ovary is a young capsule	—	100(21)

[a] Sample sizes vary because some flowers disappeared (see Text) and because I could not sample on some days.

[b] Little or no pollen remains.

[c] Flowers wet due to rain.

distances between landing platforms (tepals) to stigmas are too great for small insects to effect pollination when they first alight on landing platforms. Thus, it seems unlikely that bees (particularly small ones) exer-

TABLE 2. Nectar foragers (NF), nectar robbers (NR), pollinators (P), and pollen foragers (PF) of North American *Lilium*.

Lilium species	Floral associate	References
L. bolanderi Wats.	*Anoplodera* sp. (Cerambycidae), NR	Davis, 1956
L. humboldtii Roezl. & Leichtl.	*Apis mellifera* L. (Apidae), PF, P?	Davis, 1956
	Bombus sp. (Apidae), PF, P?	
	Calypte sp. (Trochilidae), NF, P	
	Papilio sp. (Papilionidae), NF, P	
	Halictus sp. (Halictidae), PF, P	
	Speyeria sp. (Nymphalidae), NF, P	
	Papilio rutulus Lucus, P	Grant, pers. comm.
	hummingbirds	Grant & Grant, 1968
L. kelleyanum Lemm.	*Papilio* sp., NF, P	Davis, 1956
L. maritimum Kellogg	hummingbirds	Grant & Grant, 1968
L. pardalinum Kellogg	*Papilio* sp., NF, P	Davis, 1956
	Speyeria sp., NF, P	
	hummingbirds, NF, P	
	Megachile sp. (Megachilidae)	Blanchan, 1927; Davis, 1956
L. parryi Wats.	*Bombus* sp., P?	Davis, 1956
	Celerio lineata F. (Sphingidae), P	
	hummingbird, NR?	
L. parvum Kellogg	*Andrena* sp. (Andrenidae), P	Davis, 1956
	Anoplodera sp., P	
	Bombus edwardsii Cresson, P	
	Bombus sp., P	
	Chlorohalictus sp., NF, PF, P	
	Halictus sp., P	
	Papilio sp., P?	
	Selasphorus rufus (Gmelin) (Trochilidae), P	
	hummingbirds	Grant & Grant, 1968
L. philadelphicum L.	*Crematogaster cerasi* (Fitch) (Formicidae), NR	This study
	Danaus plexippus L. (Danaidae), NF, P	
	Dialictus cressonii (Robertson) (Halictidae), NF, PF, P	
	Dialictus spp., NF, PF, P	
	Horcias dilocatus (Say) (Miridae), NR	
	Myrmica lobicornis fracticornis Emery (Formicidae) NR	
	Papilio glaucus L., NF, P	
	Phyciodes tharos Drury (Nymphalidae), NR	
	Speyeria aphrodite F., NR	
	S. atlantis Edwards, NR	
	Thymelicus lineola (Ochs.) (Hesperiidae), NR	
	Augochlorella striata (Provancher)[b] (Halictidae), PF	Graenicher, 1907
	Papilio polyxenes F., NF	
	Speyeria cybele F., P	

TABLE 2 (continued).

Lilium species	Floral associate	References
L. rubescens Wats.	*Anoplodera* sp., P	Davis, 1956
	Eulonchus tristis Loew (Acroceridae), P	
	Halictus spp., P	
	Strangalina sp. (Cerambycidae), P	
L. vollmeri Eastw.	same as *L. humboldtii*	Davis, 1956
L. washingtonianum Kellogg	*Andrena* sp., NF, PF	Davis, 1956
	Anoplodera sp., NR, P?	
	Halictus sp., NF, PF	
	Strangalina sp., NR, P?	
L. wigginsii Beane & Vollm.	*Apis mellifera,* P?	Davis, 1956
	hummingbirds, P	

[a]as *Augochlora confusa* Robertson in Graenicher (1907).

ted appreciable selective pressure on *Lilium* flower characteristics and bees commonly visited lily flowers during their initial evolution. However, small bees such as sweat bees may have been *Lilium* pollinators during much of the later evolutionary history of this genus.

Paul D. Hurd, Jr. (Smithsonian Institution), David Inouye (University of Maryland), Edward G. Voss (University of Michigan), and Verne Grant (University of Texas) offered suggestions which improved this study. Jon Herring (USDA, Washington, D.C.) identified mirids, Donald M. Weisman (USDA, Washington, D.C.) tortricids, George C. Eickwort (Cornell University) halictids and Herbert W. Levi (Harvard University) thomisids. Vouchers are placed in the museums with which the taxonomists are affiliated. I am grateful for the opportunity to work on the property of the University of Michigan Biological Station. Beatrice M. Beck kindly sent J. S. Davis' thesis from the Rancho Santa Ana Botanic Garden Library. Julia Johnson helped prepare the manuscript.

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REVIEW

INTERMOUNTAIN FLORA, VASCULAR PLANTS OF THE INTERMOUNTAIN WEST, U.S.A., by Arthur Cronquist, Arthur H. Holmgren, Noel H. Holmgren, James L. Reveal & Patricia K. Holmgren. Vol. 6. Published for The New York Botanical Garden by Columbia University Press, 562 W. 113 St. New York, 10025. 1977. 584 pp. ca $50.00.

This second volume of a six-volume series deals exclusively with Monocotyledons. Its prematurity of appearance, as volume 6, as explained in the Introduction, is due to a demand from range managers, foresters, and others for an updated treatment of the Poaceae. The region treated in this work extends from southern Idaho to southern Nevada and adjacent Arizona, and from the eastern side of the Sierra Nevada-Cascade cordillera, east to the Rocky Mountains. (Unfortunately, this information was not included in the volume.) Although regional in intent, the work has considerable interest to botanists of the Great Lakes area.

The work, of uniformly high quality, is similar in format to the earlier five-volume Vascular Plants of the Pacific Northwest (University of Washington Press). It is beautifully illustrated with line drawings, primarily by Jeanne R. Janish (many of which appeared in vol. 1 of the Pacific Northwest flora).

Perhaps most noteworthy is the treatment given the grass family. This is the first major American flora to adopt a modern phylogenetic treatment and one differing extensively from traditional treatments (e.g., Gray's Manual) at both subfamily and tribal levels. The keys designed for conventional hand lens identification techniques are artificial, leading initially to informal ''Groups''. From there the user is referred directly to the individual genera as they are grouped within tribes of the five subfamilies. For the serious student of agrostology a technical key to the subfamilies incorporates characters for which laboratory techniques are necessary. Descriptions at the subfamilial, tribal and generic levels also incorporate descriptive information not ordinarily included in older treatments (such as characteristics of the embryo, leaf epidermis, internal leaf anatomy, and lodicules). It is unfortunate that a number of errors appear in the latter information; for example, not all members of the Pooideae have embryos with non-overlapping primary leaf margins, nor do all members of the Panicoideae have embryonic leaf margins overlapping. The embryos of the Stipeae are not characterized by the absence of an epiblast, an exceptional condition which occurs in several genera elsewhere in the Pooideae, only one of which *(Bromus)* is cited.

In general, the treatment is conservative at the species level. A number of taxa treated in many previous works as species are reduced to varietal rank or submerged in synonymy (as in *Aristida*). The treatment of the wheat-grass tribe (Triticeae) is especially interesting in that the commonly occurring inter-generic hybrids within this group are accorded taxonomic status.

This work should be a welcome addition to the library of the serious amateur and professional botanist alike. It contains a wealth of information about the plants from an extraordinarily varied region.

—Stephen N. Stephenson

COMMON BROADLEAF TREES OF SOUTHWESTERN MICHIGAN: A KEY DESIGNED FOR BLIND PERSONS

Paul E. Ponchillia

Department of Blind Rehabilitation
Western Michigan University
Kalamazoo, 49008

Michael H. Fleckenstein

Gove Associates, Inc.
1601 Portage St., Kalamazoo, Mich. 49001

Many publications are designed to aid in the identification of living things, but virtually nothing is published for blind persons. Specially marked trails and guided nature tours are now available to blind people in the United States. Heisler (1944) trained blind students to tactually identify trees through the use of taxonomic keys in braille. Trees could be identified only after training in the use of keys and the meaning of botanical terms. Most standard keys rely on characteristics discernible by sight, such as number of flower parts and gross anatomy. We have attempted to design a key, on tape, which would allow a blind person, who has had no previous training, to tactually identify common broadleaf trees without guidance.

The novice does not generally use keys to identify trees, but more frequently compares the trees or parts to photographs or drawings. We felt that the nature of blindness dictates the use of a dichotomous key format because tones can be used to facilitate rapid searching for alternate statements. In our key, technical wording, when required, is supplemented by explanations comparing tree parts to parts of the human body. It was concluded that this would eliminate concept problems. Typical examples might read: ''Leaves and branches opposite, similar to the arms on a human body'' or ''Leaves and branches alternate, similar to the right arm and left leg on a human body.''

The key is based primarily on leaf characteristics, because leaves are the part most readily available to the blind user and their characteristics can be easily discriminated by touch. Characters such as bark texture, fruit type and odor are given after the common name to verify identification. Twenty-six of the most common kinds of trees (and some other woody plants) of southwestern Michigan are included in the key: Viburnum, Hackberry, Cherry, Poplar, Willow, Redbud, Osage Orange, Apple, Birch, Mulberry, Sassafras, Ash, Box Elder, Buckeye, Dogwood, as well as Maples, Oaks and Elms which are subdivided into species. Less common trees are excluded. Sufficient numbers of more difficult, yet common trees and woody plants are included to provide a challenge even to a frequent user.

The tape contains a series of pairs of statements. The user chooses the statement which more nearly fits the characteristics of the tree to be identified. A typical segment of the key reads: "Statement A. Leaves distinctly long and narrow, like the blade of a knife; Statement second A. Leaves only two to three times as long as wide, not blade-like. If you choose the first A, continue running the tape to B. If you choose the second A, run the tape fast forward until you hear the single tone for the second A." The user is guided through a series of such statements until he reaches the common name of the tree. A brief description of additional characteristics is given at that point as an aid in verifying the identification. Each pair of statements is assigned a letter and indexing tones are used to facilitate searching of the tape for alternate choices. Indexing tones are audible only on Library of Congress cassette players or on cassette players on which the fast forward and play functions can be utilized simultaneously.

It is important that the user take many opportunities to use the key in order to become familiar with it. It may, for example, be difficult to choose which of two statements more nearly fits the tree to be identified. It is also important to examine many leaves to determine size, shape, and texture, because of variation on one tree.

Conceiving of a keying technique to allow a congenitally blind person to relate plant parts to some known entity is difficult. However the body appendage arrangement seems to be the most satisfactory approach and is used in all pertinent comparisons in the key. Much time was dedicated to selecting characteristics which are distinguishable by tactile methods, such as shape, size, texture, and arrangement of leaves and stems.

The design, wording, and ease of use were tested a number of times by blind persons or blindfolded college students. The key was tested in braille and cassette tape forms. Braille proved to be too cumbersome for field use, owing to its bulky nature and the method by which it is read. The cassette form recorded at 1-⅞ I.P.S. proved to be more suitable.'

The key is easy to manipulate and can be carried in the field. It is recommended for persons from junior high school level and up. Due to the conceptual problems faced by congenitally blind persons, we may have overlooked ways to make the key suitable to the needs of the users. Consequently, we would appreciate critical comments. A limited number of copies of the key are available on loan from the Department of Blind Rehabilitation, Western Michigan University.

The folowing is a small portion of the key written the way it appears on the tape. The first tone designation is for the second B. The second A is too far into the key to make its inclusion practical.

A. Leaves and branches opposite, similar to arms on a body. Second A. Leaves and branches alternate, similar to right arm and left leg on a body. If you choose the first A continue running tape to B. If you choose the second A run the tape fast forward until you hear the single tone for the second A.

B. Leaves simple, that is, one leaf blade per leaf. If the attachment point breaks off evenly or is curved or cup-shaped, you have one leaf. Second B. Leaves compound, that is, many leaf blades or leaflets per leaf. Leaflet stems usually tear unevenly from attachment points and will be attached to smoother non-woody stems. If you choose the first B, continue running the tape to C. If you choose the second B, run the tape fast forward until you hear the two tones for the second B.

C. Leaves divided forming three to five lobes similar to fingers on the hand. Depth of divisions between lobes may vary among kinds of trees. If this is not true, continue to the second C. If this is true, the tree is a maple. Seeds, when present, attach as pairs at one end forming a V-shape. The seeds are thick at the attached end and thin like paper at the other end, much like wings.

> Species of maples: leaves approximately hand size or less, divisions between lobes reaching or nearly reaching the mid-rib; this is a SILVER MAPLE. Leaves hand size or less, divisions between lobes reaching only half way or less to the mid-rib; this is a SUGAR MAPLE. Leaves approximately one and one half times the size of hand, leaf stem when broken from a branch containing sticky juice; this is a NORWAY MAPLE.

Second C. Leaves not lobed, that is, edges of leaf blade not divided. Continue to D.

D. Leaves with saw-toothed edges. If this is not true continue to the second D. If this is true the tree is a VIBURNUM. This is a shrubby tree. Fruit, if present, a small round berry up to one quarter inch thick in a dense cluster at the end of a branch.

Second D. Leaves with smooth edges, not saw-toothed. These are the dogwoods. These are small trees. If fruit is present, it will be a small round berry up to one eighth inch thick in small clusters at the end of a branch.

(Two tones) B. This is the second choice under B. Leaves compound, that is, many leaf blades or leaflets per leaf. Continue to C.

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SUBSCRIPTION PRICE INCREASE

Scientific journals are not immune to the effects of inflation. We must increase our annual subscription to $8.00 to cover rising costs of printing, paper, and postage. This increase will take effect with vol. 19 (1980), five years after the previous increase. Members of the Michigan Botanical Club will continue to receive the journal as one of the privileges of membership, but club dues will also have to rise. Back issues, when available, will remain at $3.00 per volume for vols. 1-13 and $5.00 per volume for vols. 14-18. Page charges for articles more than 10 printed pages in length have also been increased to $30.00 per page beginning with manuscripts received April 1979.

The March issue (Vol. 18, no. 2) was mailed May 14, 1979.

CONTENTS

Vegetation Changes Following a Water Level Rise and Tree Mortality in a Michigan Bog
Christa R. Schwintzer 91

Studies on Tricholoma vaccinum and Tricholoma imbricatum in North America
Clark Ovrebo and Alexander H. Smith 99

Stropharia riparia, a Previously Undescribed Species Suspected of Occurring in Michigan
Alexander H. Smith 107

Flower Biology and Arthropod Associates of Lilium philadelphicum
Edward M. Barrows 109

Review 116

Common Broadleaf Trees of Southwestern Michigan: A Key Designed for Blind Persons
Paul E. Ponchillia and Michael H. Fleckenstein 117

Subscription price increase 119

On the cover: Jeffersonia diphylla, *Twinleaf, one of Michigan's Rare Species, Horner's Woods, Washtenaw County. The genus was named in honor of Thomas Jefferson. Photo by Richard Pippen, May 1977.*

8

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A STUDY OF BAKER WOODLOT
I. PHYSICAL AND HISTORICAL DESCRIPTION

James H. Beach[1] and W. D. Stevens[2]

Dept. of Botany and Plant Pathology
Michigan State University
East Lansing, 48824

Baker Woodlot is a biological island on the campus of Michigan State University in East Lansing. It represents in part the beech-maple climax forest which once covered the campus and a significant portion of the lower Great Lakes region and is in part the result of a variety of human influences.

This report is the first in a series of three papers in which we will attempt to characterize the vegetation of the woods. We also hope to document the major factors which have influenced the composition of the contemporary forest. It is the third study of its kind on forested areas of the university campus; Beaman (1970a, 1970b) and Frye (1976a, 1976b, 1977) have published studies on Sanford Natural Area and Sandhill Woodlot, respectively.

The study was initiated by the junior author in 1969. The senior author joined the project in 1973, and we have collaborated through the preparation of the final manuscript. This article deals mainly with historical aspects of the vegetation along with a brief description of the local physical environment. The second paper is ecological in nature and will include comparisons of the flora in Baker with that of nearby woods. The third is a checklist of vascular plants. In addition, Dr. Richard C. Harris of the University of Michigan Herbarium has completed a lichen and bryophyte checklist which will be published at a latter date.

PHYSICAL SETTING

Baker Woodlot (located in the SW¼ of Section 19, T4N, R1W, Ingham County) is in the southern part of the developed campus, bordered on the north by Service Road, on the west by Farm Lane, on the south by the Chesapeake and Ohio Railroad, and on the east by Bogue Street to the north and abandoned fields to the south. It is the largest wooded area on the campus, comprising 73 acres (Fig. 1).

From the data of a 1911 topographic map (Anon., 1911) and current bench mark records, the altitude varies from 854 to 872 feet above sea level (Fig. 2). The northeast, central, and southern parts of the woods

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[1] Present address: Dept. of Botany, University of Massachusetts, Amherst, 01003.

[2] Present address: B. A. Krukoff Curator of Central American Botany, Missouri Botanical Garden, 2345 Tower Grove Ave., St. Louis, 63110.

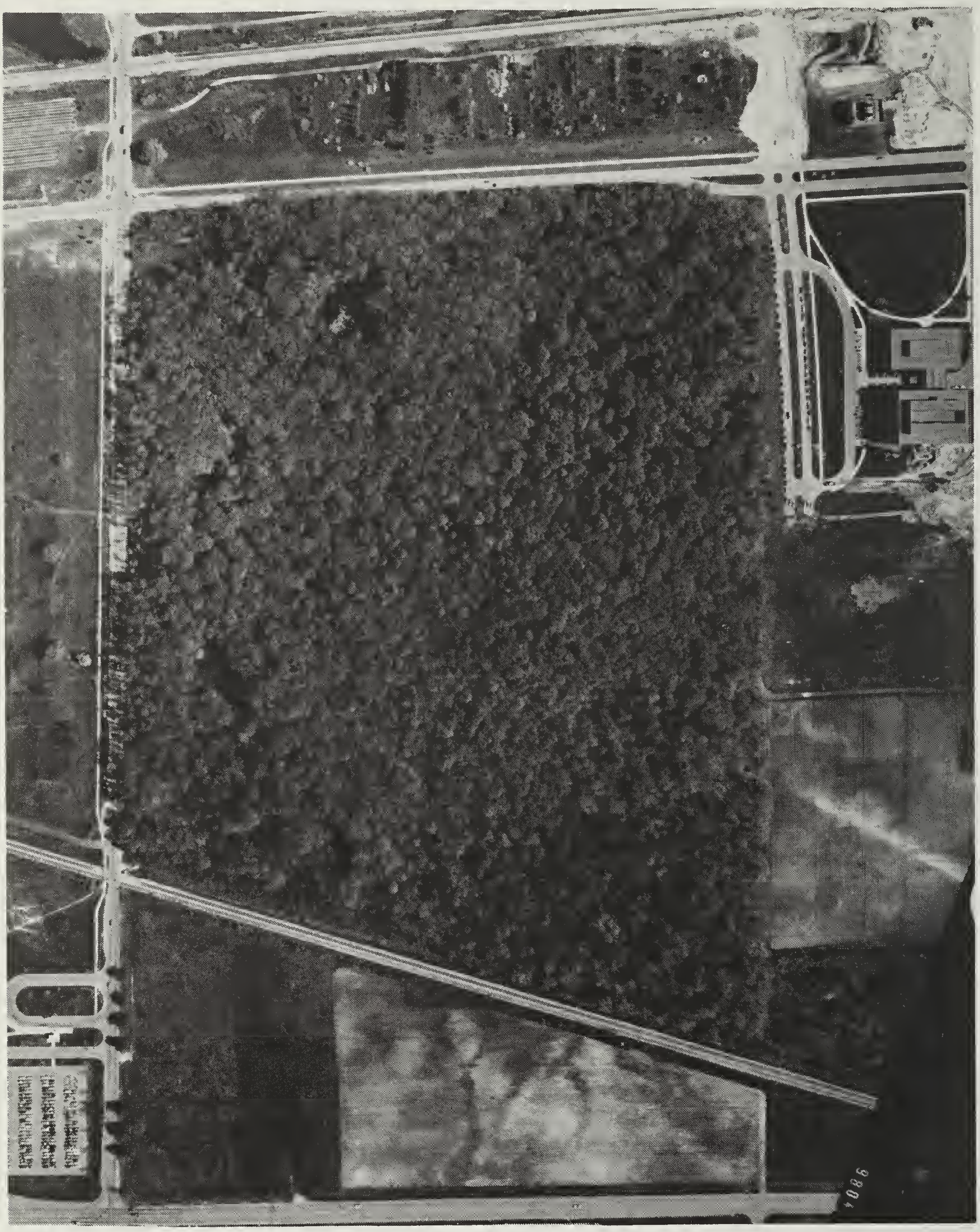
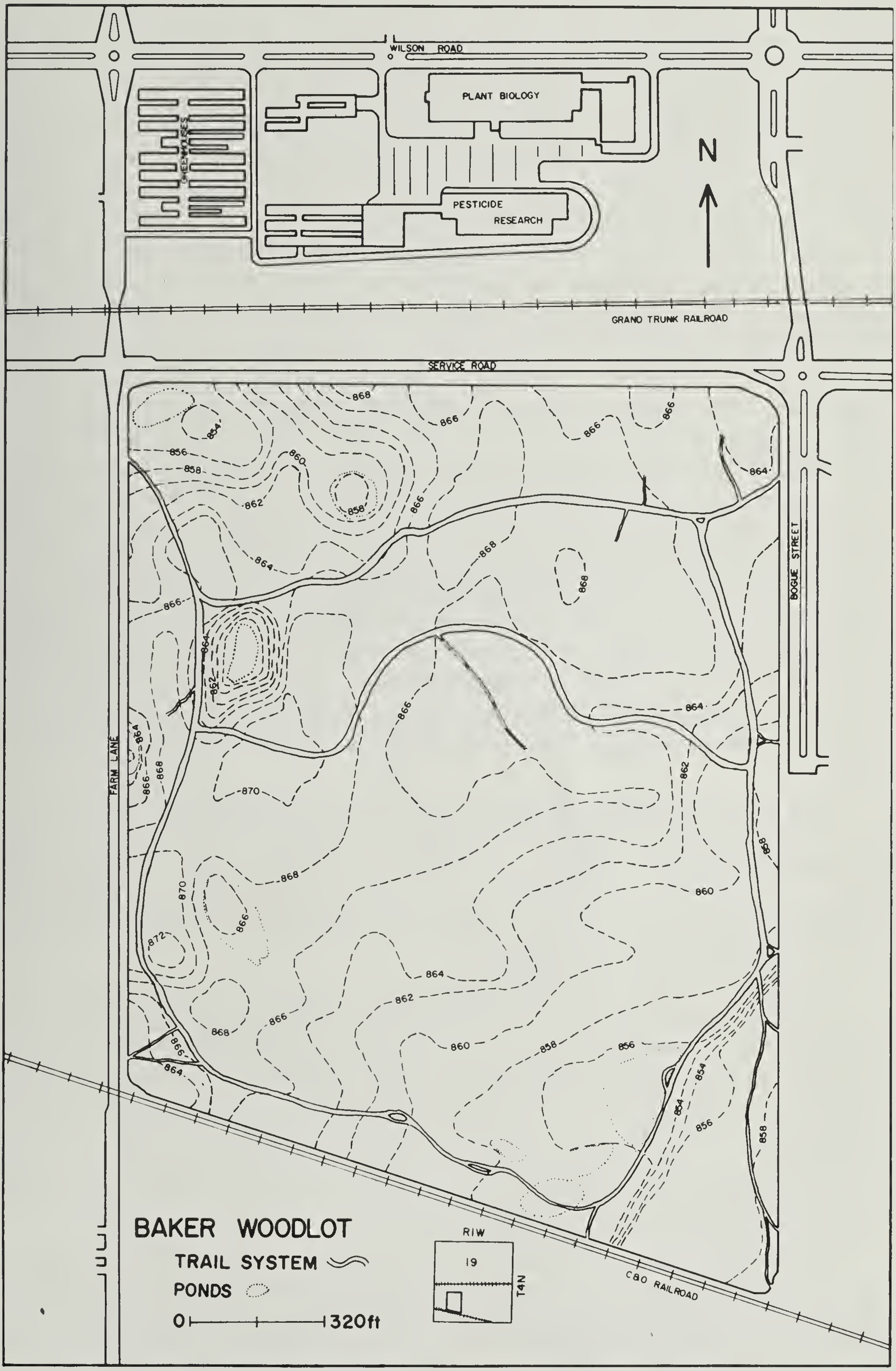


Fig. 1. A vertical aerial photograph of Baker Woodlot. Gaps in the canopy on the left half of the photograph indicate the locations of the western ponds. Photograph by Abrams Aerial Survey Corporation, Lansing, Michigan, taken on 20 May 1974.

have little relief. The western part contains five major ponds. A large amount of the area in the southern third, particularly to the east, is covered with water in the spring and early summer. The general slope is from the west and northwest to the southeast. The distribution of soil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GREENHOUSES
PESTICIDE RESEARCH
N
GRAND TRUNK RAILROAD
SERVICE ROAD
FARM LANE
BOGUE STREET
C&O RAILROAD
BAKER WOODLOT
TRAIL SYSTEM
PONDS
0
320ft
R1W
19
T4N
852
854
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866
868
870
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Fig. 2. A topographic map of Baker Woodlot.

types in the woodlot is illustrated in Fig. 3. The soil series represented, Barry, Brookston, Conover, Hillsdale, Locke, and Spinks, are all typically found on moraines and till plains of Wisconsin age.

Due to its inland locality, the climate of East Lansing is primarily continental in nature, although it is at times modified by the Great Lakes influence, which tends to moderate temperature extremes. The coldest month is January with a mean temperature of 23°F (except where otherwise noted, all temperatures and precipitation data are based on the period from 1940 to 1969; data from the Michigan Weather Service, East Lansing). The mean daily maximum for January is 29.9°, the mean daily minimum 16.0°. The warmest month is July, with a mean temperature of 70.5°. The mean daily maximum for July is 81.8°, the mean daily minimum 59.1°. July 1921 had the highest mean temperature on record, 77°. The lowest monthly mean temperature on record was 8° in February of 1875. East Lansing averages nine days a year with daily maxima greater than 90°. From November to March, 84% of the daily minima are 32° or below. The average freeze-free period (growing season) is 151 days a year. The mean annual precipitation in East Lansing is 30.1 inches. February is the driest month, with a mean of 1.4 inches; June is the wettest month with a mean of 3.8 inches. The greatest monthly precipitation on record was in June 1883, with 11.4 inches. The driest months on record were August 1894 and February 1877, with no precipitation. The average annual snowfall is 38.8 inches, with an average of 65 days a year with one inch or more of snow on the ground. The average annual sunshine is 54% of the total possible. The prevailing wind is southwesterly and averages 11 miles an hour.

The exposure of the woodlot to pesticides is uncertain. The University has sprayed the American elm trees on campus for many years, but the formal policy has been not to spray wooded areas (Dr. George Parmelee, Campus Park and Planning, M.S.U., pers. comm.). There is a possibility that the Lansing Vector Control may have applied DDT or other insecticides for mosquitos.

In recent years we have noted that the narrow strip running the length of the south side of the woods (north of the railroad) has often been sprayed with an herbicide. This presumably is to keep the woody vegetation from encroaching on either the railroad bed or the low telephone lines which run along this border. In 1976, many trees along the margin of the woods were exposed to the spray and showed serious damage. At least one species, *Populus canescens,* was apparently eliminated from the flora on this occasion. The spraying, however, maintains an open habitat and several herbaceous species occur only in this part of the woods.

The physical aspect of the woods is known to have been disturbed a few times since the turn of the century, the period for which records exist. The first known disturbance was the construction of a drainage ditch in the southeast corner (Figure 1). A U.S. Dept. of the Interior Geological Survey map made in 1911 from a 1909 survey (O. Smith, 1911) shows an intermittent stream running through this area; a 1910 map (Figure 4)

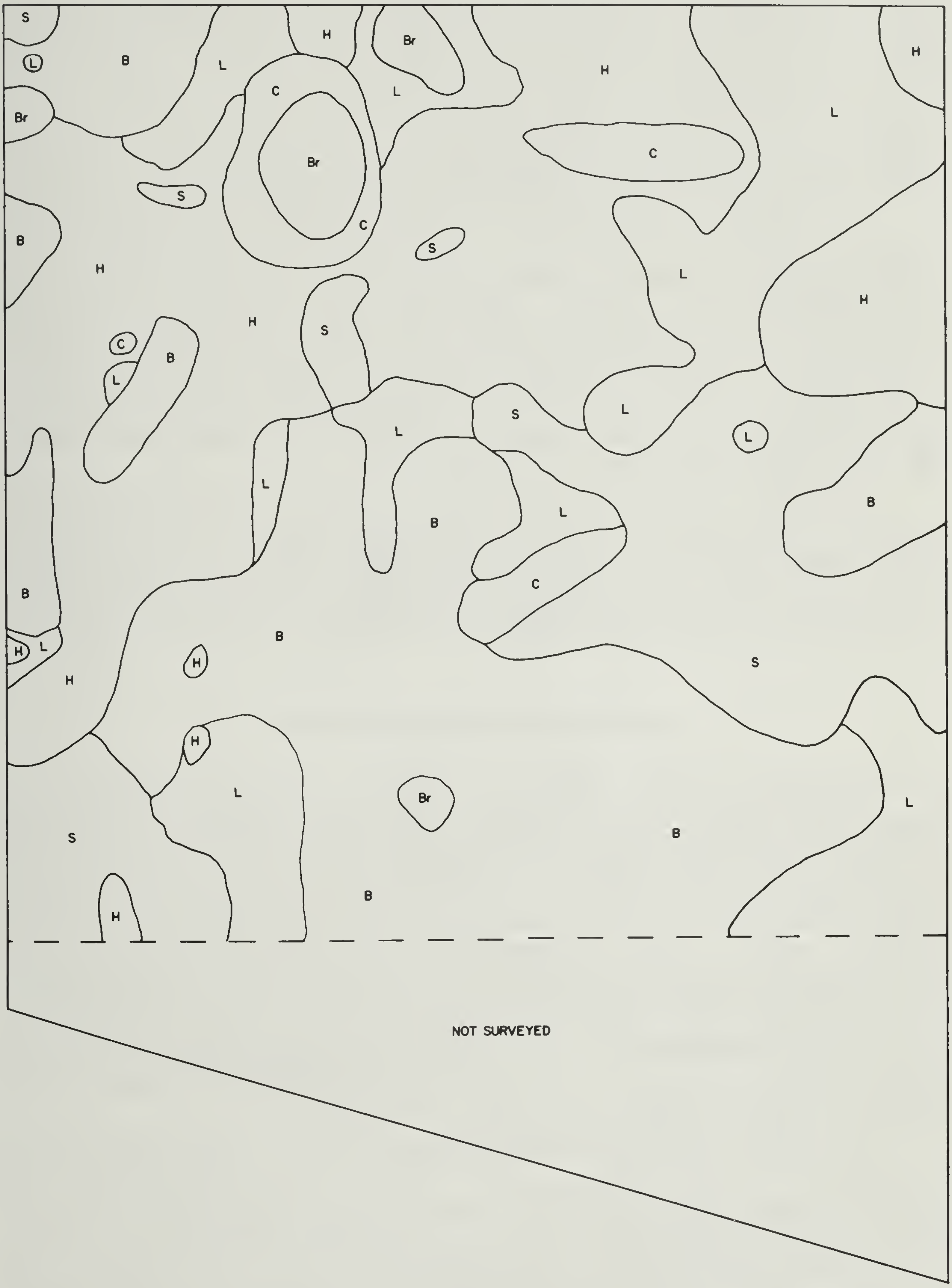

Fig. 3. Soils map Baker Woodlot. B: Barry loam, fine textured and poorly drained. BR: Brookston silty clay loam, fine textured and very poorly drained. H: Hillsdale sandy loam, coarse textured and well drained. L: Locke sandy loam fine textured and somewhat poorly drained. S: Spinks loamy sand, coarse and well drained. (After a 1969, unsigned soils map in the files of the Forestry Department, M.S.U.).

shows the drainage ditch. At present, a 24–inch subterranean drain pipe runs through the corner of the woods along the base of the ditch. This is a segment of a drain which begins far to the south of the woods and continues north to where it enters the Red Cedar River just to the west of Hagadorn Road (Mr. James Simons, Physical Plant, M.S.U., pers. comm.). Based on a date inscribed in a concrete basin located in the path of the drain, the drain was probably laid through the woods in 1934.

In 1970, Service Road was constructed along the northern edge of Baker Woodlot to facilitate traffic flow to the newly constructed Medical School complex, located to the east of the woods. During the construction, about 20 trees, primarily sugar maple and red oak, were cut in the northeast corner. In the northwest corner, a few planted black walnuts were removed to make way for a steam pipe which was laid just to the south of the road. European birch and eastern white pine were planted in the northeast and northwest corners, respectively, presumably to reduce the open areas caused by the cutting.

Alterations of the paths are the only other conspicuous physical changes in the woods. The north-south path near the western edge has been coated with cinder along part of its length. The date of this addition is unknown. A more serious change is the expansion of the trail system as a result of increasing foot traffic.

ADMINISTRATIVE HISTORY

On June 16, 1855, the State of Michigan purchased 676.57 acres of land from A. R. Burr of Lansing in order to construct an Agricultural College. In that year, the college was established in order that the scientific study of agriculture could be carried out (Beal, 1915). At the time of the purchase, the land was almost completely covered with a dense forest (Crozier, 1896). At first, a small area was cleared at the northern end of the tract for the college buildings. As the college grew, the elimination of the forest progressed farther to the south. Much of the forest was harvested to provide wood for fuel and lumber for the construction of classroom and dormitory buildings (Beal, 1915). The Farm Department of the college had the original jurisdiction over the grounds.

The area now known as Baker Woodlot is located near the southeast corner of the original land purchase. "Field 17," as it was then known, was not the discrete area it is today. Except for the railroads to the north and south, the woodlot was continuous with the rest of the College forest.

By 1894, however, most of the original purchase had been cleared and converted to cultivation or grazing. By that time the wooded areas of the college comprised approximately 155 acres (C. D. Smith, 1897). Most of this acreage was shared by two parcels (Crozier, 1896). One tract was adjacent to the Red Cedar River in the eastern part of the present campus. At that time known as the North Woodlot, today this woods is called the Sanford Natural Area. The larger tract, Field 17, later was called South

Woodlot, then Farm Lane Woodlot, and finally, in 1941, Baker Woodlot, after two early foresters at the college, James Fred Baker and Harry Lee Baker (pers. comm. P. A. Herbert, Director Emeritus of the Division of Conservation, who was head of the Forestry Department at the time). H. L. Baker eventually became the first State Forester of Florida. J. F. Baker was appointed Professor of Forestry and Chairman of the Forestry Department on October 1, 1970 (Beal, 1915). He was the second Chairman of the Forestry Department and held that position until he left the college in 1915 (Anon., 1953).

In 1894 the State Board of Agriculture, the governing body of the college, at the urging William James Beal, Professor of Botany and Forestry, resolved that the remaining college woodlands, which were but a remnant of the original forest, be placed in such a condition as to illustrate the proper methods for managing woodlands for continuous and lasting profits (Beal, 1896; Crozier, 1896). Professor Beal was authorized to take the "necessary measures" to carry out the wishes of the board (C. D. Smith, 1897).

Eight years later, on November 17, 1902, the Board of Agriculture transferred jurisdiction of the college woodlands to the recently established Department of Forestry (Bogue, 1903). Baker Woodlot has since remained under the control of that department.

VEGETATIONAL HISTORY

Record of disturbance in the woods begins about the middle of the 19th century, but even before then fire and cutting probably had a significant effect on the vegetation. Schneider (1966) emphasized that fire, natural and man-made, was an important factor influencing the vegetation of Michigan. The historical information that is available to us has been generated since the founding of the university in 1855.

The Annual Reports of the State Board of Agriculture are the primary sources of information, often mentioning cutting and other activities on the forests of the "College Farm." Additional information is found in the historical files of the Department of Forestry in the form of management programs, memoranda, letters and other papers. Unfortunately, accurate information on the nature and extent of many activities in the woods has gone unrecorded.

The vegetation of Field 17 is first specifically mentioned in the report of 1877. C. L. Ingersoll, Professor of Agriculture and Head of the College Farm Department, noted that "Field 17 . . . is all timber." (Ingersoll, 1878a). In the following year (1878b) he reports, "Field 17 remains the same as last year."

The next description of the vegetation of Baker Woodlot appears two years after the Board of Agriculture's resolution to preserve the remaining college woodlands; the Professor of Agriculture in that Annual Report (1896) states in reference to Baker Woodlot (C. D. Smith, 1896):

> The third lot between the two railroads contains in its northeast corner an area of 7.8 acres from which nearly all the large timber was cut for fuel in the winter of 1892–3. The remaining trees have now been cut from this portion, leaving only the saplings and younger growth, to exhibit as nearly as possible the natural method of reforestation when the large timber is all removed at one time. On the south side of the woodlot, along the D., L. & N. railroad, fire break four rods wide has been cut, from which all timber has been removed. This strip is intended especially as a guard against fires coming from the railroad, and will be planted to corn and the other cultivated crops. This woodlot, like the one mentioned, has been laid off in wards for the purpose of description.
>
> The general condition of the woodlands of the College farm is now poor, much of the best timber having been removed for lumber and fuel. Some of the remaining large trees are dying from exposure and fire, and will be cut and used for fuel as soon as practicable. Nearly the whole surface of the two larger woodlots, however, is covered with a thick growth of young timber, much of which in time will be valuable if protected against injury by live stock and fire.

In the same year, Professor Beal gave his evaluation of the forest (Beal, 1896): "This farm, which originally contained rather more than a square mile, and consisted almost entirely of virgin forest, has been cleared, until now little more than two hundred acres remains of what, by a charitable construction, may be termed woodland." In a later study, R. H. Westveld (1935a) refers to a "very heavy cutting, virtually a clear cutting in 1896." Evidently, Field 17 was in relatively poor condition.

No mention of further disturbance in the woods is made until 1902 when Professor Beal (1902) wrote: "Two men worked most of the winter cutting stove wood and three-foot wood in the woods north of the Pere Marquette." This somewhat vague description was presumably in reference to Field 17. The Pere Marquette (Railroad) is now the Chesapeake and Ohio Railroad which runs along the south edge of the woods.

In the Annual Report of 1903 (Bogue, 1903) stated:

> On the south side of field 17 improvement cuttings have also been made. Acorns, bitternuts, and two quarts of locust seed, and 100 young basswood trees 36 inches high have been planted where the trees were taken out. On May 18, fire ran over about five acres of this place and beside burning three cords of 36-inch wood and doing other damage probably destroyed a part of the planting. A few hundred locust trees 18 inches high were planted on part of the area burned over.

Additional plantings were made in the woodlot in the following year (Bogue, 1904). Another report (Conant, undated) makes reference to "repeated fires"in the southwestern part of the woods.

Each year from 1906 to 1909 mention is made in the Annual Reports of tree planting in the College woodlands. Thousands of trees, mainly black locust, chestnut, and white ash, were planted. The stock was obtained from the Forestry Department Nursery (Bogue, 1906, 1907; Baker, 1908, 1909).

J. C. DeCamp, who received a B.S. degree from the college in 1910, wrote a senior thesis on Field 17 (DeCamp, 1910). This paper is a "working plan," that is, a management plan, for the woods. The thesis is of interest especially because it includes a crude map of the vegetation of the woods (Fig. 4) and a diameter-class table for the trees six inches d.b.h. or larger. There is no evidence that his management plans were ever implemented by the Forestry Department.

A. K. Chittenden (1919), Professor of Forestry, wrote: "Experiments carried out in Woodlot 17 showed that this woodlot was growing at the rate of approximately six short cords per acre per year. Four hundred cords were accordingly cut, this being practically one years growth. The wood was a large factor in relieving the fuel shortage. The Woodlot is in excellent condition."

For the period between 1921 and 1932, "improvement" cuttings in Field 17 are regularly noted (Chittenden, 1921, 1922, 1923, 1928; DeCamp, 1931; Herbert, 1932). These cuttings seem to have been relatively small and selective. No information on the species removed has been found.

A note by Van Camp (1933) entitled "C.W.A. Work in Woodlot 17" makes several suggestions for work to be done in the woodlot. J. L. Van Camp was superintendent of the Forestry Nursery at the time. His most substantial proposal was for the cleaning of a strip 50 to 75 feet wide along the entire west edge of the woods. The cleaning was to include cutting some of the denser areas and pruning the branches below the six foot level. He also wanted to "grub out" some of the black locust along the southern edge which were preventing motorists from seeing the railway. He proposed that the "wet places" on the west side of the woods be drained. According to Professor Herbert (pers. comm.), some of Van Camp's proposals were carried out. To the best of Herbert's recollection, some cleaning was done, and a few black locusts removed. No attempt was made to drain the ponds on the west side of the woods.

In 1935, R. H. Westveld, a member of the forestry faculty, established two one-acre experimental plots in the north-central part of the Woodlot (Westveld, 1935a). One plot was clear cut, the other selectively cut. Westveld hoped to illustrate, on the basis of measurements taken at five-year intervals, the difference in growth rates in the two areas. According to Professor Victor Rudolph (pers. comm.), these areas were never measured. The plots were in the central part of the woods,

Westveld also studied a third one-acre plot in the woods where no cutting was done. The growth rates of the trees were determined over a five-year period (Westveld, 1935b, 1935c). A map in the Forestry Department files (Fry, 1940) shows the plot to be in the northeastern woods.

Another working plan, unsigned and undated, is in the forestry files (Anon., undated). Based on information contained within, this otherwise remarkably thorough report was written in late 1939 or early 1940. Much of it deals with the local timber industry and related economic considerations. The author does, however, provide a table of the tree composition of the woodlot and information on the condition of the stand:

> The range in age in the Woodlot is from the seedling stage to overmature decadent trees. In general, the representation of the various age classes in the woodlot is good, although the distribution on the ground is patchy. A heavy improvement cut-

> ting during the winter of 1938–1939 removed many of the overmature decadent trees, and the stands are now in good condition . . . Nearly every year some cutting has been done but it is unfortunate that the record of these cuttings and plantings are spasmodic, incomplete, and unreliable.

Once again, no evidence exists that the management directives in this document were implemented. Subsequent, but fragmentary evidence suggests that they were not.

According to Professor Rudolph, the last general improvement cutting was in 1947. A letter from Professor Herbert to E. L. Anthony, Dean of the School of Agriculture (a copy of which is in the Forestry Dept. files), mentions that this cutting was taking place in the eastern part of the woodlot. Although no information has been found on the extent of the cutting, a student project on some of the felled trees (Hortin, 1947) provides some interesting information. The student counted the growth rings of some of the larger trees cut. Included in these counts was a red oak of 105 years (1842), a 126–year–old American elm (1821), and a sugar maple of 130 years (1817), in addition to a beech with 144 rings (1803).

A document entitled "Suggested Objectives in the Management of the Campus Woodlands of the Michigan State College" was prepared by Professor Herbert in 1949. He proposed a set of priorities of woodlot management: "First, to provide maximum assistance to the teaching of Forestry to enrolled students, second, to further research, third, to provide demonstration areas of correct forestry practices for farmers and others interested therein and, fourth, to provide forest recreational facilities for students and others." Professor Herbert's management plan divided Baker Woodlot into five units and most of the woods was to be further subdivided into one-acre blocks. These blocks were to be individually clear cut at five-year intervals. According to Professor Herbert (pers. comm.), this part of his plan was never carried out. Some other suggestions, including the clearing of bridle and foot paths and the creation of wildlife cutting plots, were implemented.

The wildlife cutting plots were to "be managed from the viewpoint of producing wood and such game as raccoon, squirrels, pheasants and rabbits and song birds" (Herbert, 1949). The project was under the direction of Dr. L. W. Gysel of the Department of Fisheries and Wildlife. Twenty-eight plots, each 100 feet square, were laid out in two rows along the southern edge of the woods. Alternate plots were clear cut between 1950 and 1953. Gysel (1953) provided an inventory of the trees (1 inch or more d.b.h.) in each of the plots. No follow-up study was attempted after the original cutting.

In 1953, Putnam W. Robbins, at the time on the forestry faculty, began studies on maple sap yields in the northeast corner of the woods. Professor Robbins' studies in Baker continued through 1961 and considered the effects of a variety of factors on the quantity of sap flow (Robbins, 1960, 1965; Costilow et al., 1962).

The last formal management program was prepared in 1957 (Rudolph, 1957). As with most of the earlier programs, the purpose of this plan was to provide "a model managed woodlot on Campus as a demonstration of good woodlot management practices.'' This program has been restricted to a ten-acre area in the northeast corner of the woods, and has been under the direction of Professor Rudolph since its inception in 1957. The area is subdivided into five parts, each consisting of two acres, within which every tree larger than 3.5 inches d.b.h. is identified with a number. Every five years a 100% inventory is taken of the numbered trees and based on these inventories, a single two-acre plot is selectively cut each year on a five year cycle. This design attempts to optimize wood production by allowing faster growth of the smaller trees.

Two additional management programs in the forestry files were student exercises which were never meant to be implemented. They are noted here for sake of completeness (Gammon 1958; Burde et al. 1968).

NURSERY USES OF THE WOODS

Several large trees of *Robinia pseudo-acacia* and *Pinus ponderosa* present along the south edge of the woods are apparently relicts of a nursery in that area around the turn of the century. The 1910 map of the woods (Fig. 4) shows this area. We have been unable to find additional references as to the duration or extent of the nursery. Another plantation which has left descendants in the present forest was located in the northwest corner of the woods. In 1910, a one-acre plot of alternating rows of *Juglans nigra* and *Thuja occidentalis* was established. With the exception of one remaining tree, the thujas have been removed from the area. The black walnuts have been thinned several times since 1910, and detailed measurements of their growth have been taken. The 68–year–old stand is one of the oldest black walnut plantations in southern Michigan (DeCamp 1910; Rudolph & Robbins, 1956; Rudolph et al., 1972). In recent years several individuals have died as the result of poor soil drainage partially caused by the road construction along the north edge of the woods in 1970. These dead trees were cut in 1973. Today there are about 50 black walnuts in the area.

INSTRUCTIONAL USES

Like the other campus woodlots, Baker has been used for many decades for instruction and research in various aspects of forestry, along with taxonomy, ecology, entomology, environmental education, herpetology, ornithology, and mammalogy. In 1970–71, over 19,000 student hours of instruction and research occurred in the woods (Gysel, 1971). One class project in 1925 had a more lasting affect than the instructor anticipated. P. A. Herbert (pers. comm.), at that time Assistant Professor of Forestry, wanted to give his silviculture class some experience in planting trees and had his students plant seedling Douglas firs inside the woods along the western edge assuming that a shade intolerant species would never persist in the dark understory. Today along the west side of the

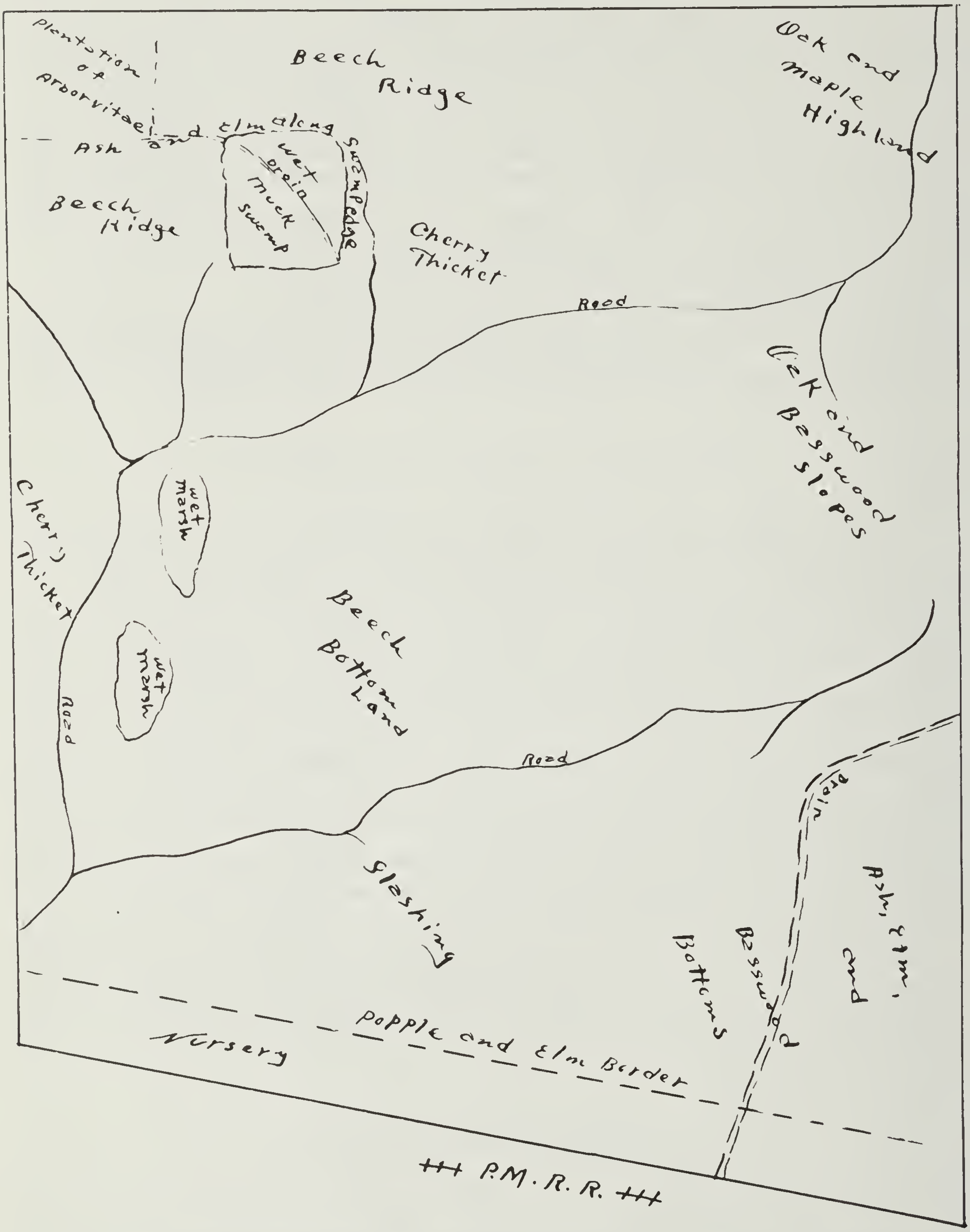
Plantation of Arborvitae
Beech Ridge
Oak and maple Highland
Ash and Elm along Swamp edge
wet drain
Muck Swamp
Beech Ridge
Cherry Thicket
Road
Oak and Basswood slopes
wet marsh
Cherry Thicket
Beech Bottom Land
wet marsh
Road
Road
Drain
Slashing
Ash, Elm, and
Basswood
Bottoms
Popple and Elm Border
Nursery
P.M.R.R.

Fig. 4. A 1910 map of Baker Woodlot, modified from DeCamp's manuscript (1910).

woods there are still a few dozen Douglas firs barely hanging on. Although they are now over 50 years old, most are but a few feet high and one to two inches in diameter.

SUMMARY

Baker Woodlot is a 73–acre beech-maple woods on the campus of Michigan State University. The woodlot has a long history of disturbances, mostly in the form of numerous selective cuttings. The Annual Reports of the State Board of Agriculture, along with management program documents, memoranda, and assorted other papers in the Forestry Department files, give some indication of the extent of activity in the woods since the founding of the university in 1855. The periodic selective cuttings have undoubtedly affected the present forest, the composition and structure of which will be discussed in the following papers.

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Two people have assisted throughout the duration of this project and to them we are particularly grateful. Dr. V. J. Rudolph provided access to the Forestry Department historical files, helped with several historical aspects, and suggested improvements in the manuscript. We are in the debt of Dr. J. H. Beaman for his continuous support. The study has been improved substantially by his criticisms, ideas, and generosity with his time, field data, herbarium facilities, and editorial improvements.

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NOTABLE VASCULAR PLANTS OF THE RED LAKE PEATLAND, NORTHERN MINNESOTA

Gerald A. Wheeler and Paul H. Glaser

Dept. of Botany
University of Minnesota
St. Paul, 55108

The Red Lake Peatland, situated just north of Upper Red Lake in north-central Minnesota, occupies an area that was formerly the eastern arm of Glacial Lake Agassiz. The core of the peatland covers approximately 450 square miles in northeastern Beltrami County and adjacent parts of Koochiching and Lake of the Woods Counties. During the summer of 1978, the writers engaged in ecological and floristic studies in the core area with the purpose of establishing a classification of plant communities to be used as a basis for mapping the vegetation. This paper deals with taxa that have not been reported for Minnesota or have been collected only a few times in the state. (The letters W and G refer to specimens collected by the writers and W. A. refers to the Waskish Airport. All specimens cited are deposited in the University of Minnesota Herbarium.)

The Red Lake Peatland consists of a complex mixture of ombrotrophic bogs whose surfaces receive water only from atmospheric precipitation and minerotrophic fens which receive in addition water that has its source in adjacent mineral soil. The peatland extends approximately 50 miles east to west and nine miles north to south. It can be roughly divided from west to east into four main areas: the Great Western Patterned Fen, the Divide, the Ludlow Patterned Fen, and the Koochiching Raised Bog Area.

The physiographic features of the Red Lake Peatland have been described by Heinselman (1963), Hofstetter (1969), and Griffin (1977). The Great Western Patterned Fen consists of a single water track studded with small forested islands. The track, about two miles in width, carries mineral-rich water eastward for a distance of about 20 miles to the Divide.

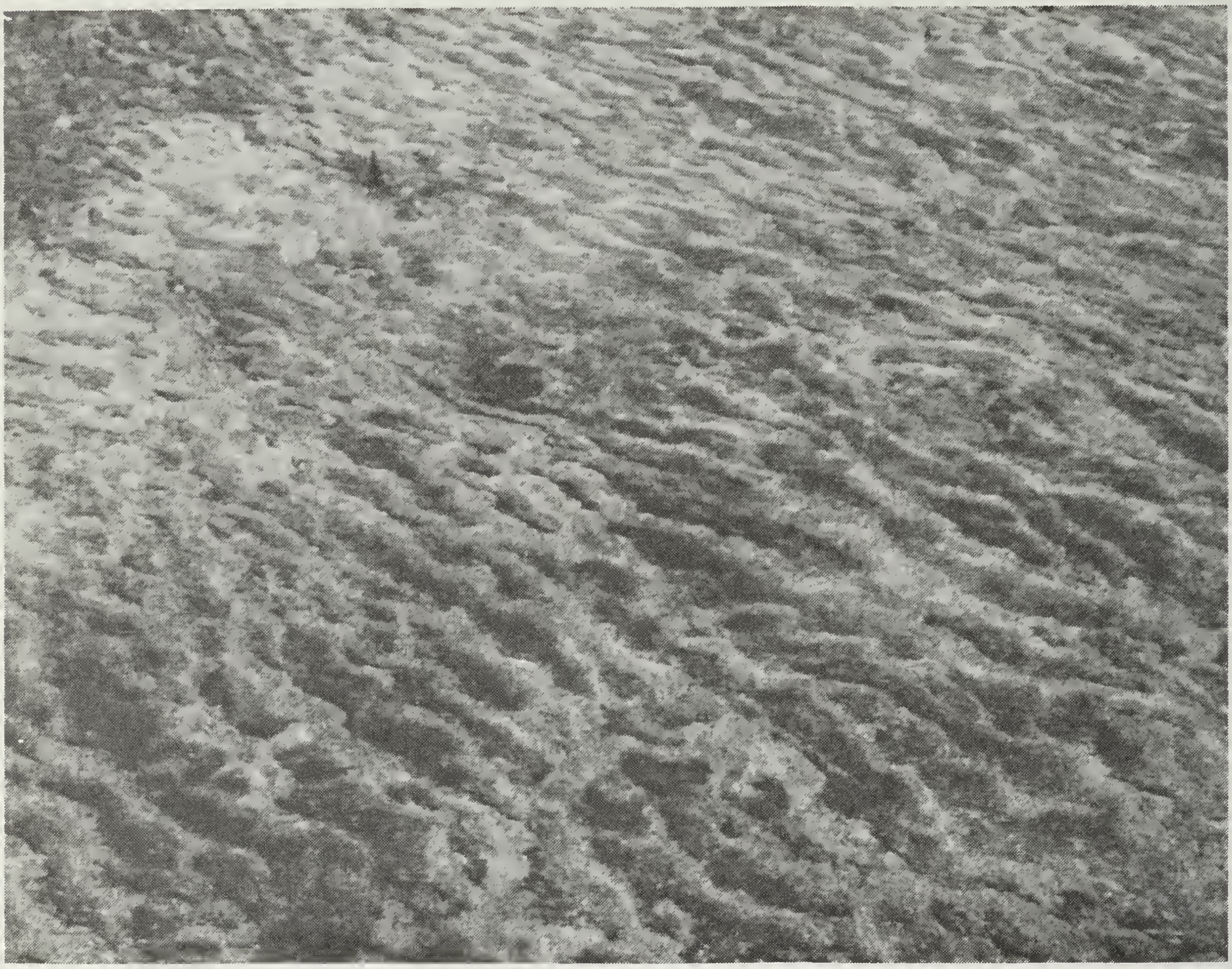

Fig. 1. The flark-and-string pattern of vegetation so typical of the Red Lake peatland fens. Dark-colored areas are strings; light-colored areas are flarks. Flow of water is from the lower left to the upper right.

The water track is, for the most part, a treeless sedge fen composed of watery depressions, or flarks, and rather low, sinuous ridges, or strings. The alternating flarks and strings are always oriented at right angles to the water flow. A water track with alternating flarks and strings is called a ribbed fen. The single water track bifurcates at the western edge of the elevated area known as the Divide. One branch curves southward to Upper Red Lake, while the other curves northward to the Rapid River. Each branch is a ribbed fen dotted with small forested islands. The Divide consists of elevated ombrotrophic bogs, many of which are sharply bounded by extremely narrow water tracks which also show the ribbed fen pattern. In these narrow ribbed fens one occasionally finds non-vegetated areas of open water. These areas of open water, or fen pools, vary in size and generally have a rounded outline. The Ludlow Patterned Fen lies immediately east of the Divide. It is a ribbed fen in which the flow of water is east to west but turns northward to the Rapid River at the eastern edge of the Divide. The Ludlow Fen is interrupted by a major north-south highway and several drainage ditches, the latter of which also penetrate into the Divide and for a short distance into the Great Western Patterned Fen. The Koochiching Raised Bog Area, which forms the easternmost portion of the peatland, is another area of elevated ombrotrophic bogs. To date, the field activities of the writers have been mainly confined to areas west of the north-south highway. The plant communities of the ombrotrophic bogs are distinguished by low species diversity and high acidity. In contrast, the communities of the minerotrophic fens are distinguished by higher species diversity and lower acidity. (A detailed description of the peatland communities will be treated later.)

Xyris montana Ries was found on the edge of fen pools at two localities. At both stations it was associated with *Carex livida* var. *grayana, Rhynchospora alba, R. fusca, Utricularia cornuta, Pogonia ophioglossoides,* and *Juncus stygius* var. *americanus.*

Beltrami Co.: 14 mi. NW of W. A., T156N, R32W, Sec. 24, W & G 3041. Koochiching Co.: 10.5 mi. NNE of W. A., T156N, R29W, Sec. 16, W & G 3362.

X. montana was previously known in Minnesota from single localities in Itasca and St. Louis Counties, but this is the first published report from the state. According to Scoggan (1978) and Fernald (1970), it is a plant of eastern Canada with only limited local extensions into the United States, only a few of them west of Michigan. The Red Lake Peatland contains the westernmost known stations in North America.

Drosera anglica Huds. grows in flarks of patterned fens throughout the peatland; it is most often associated with *Carex lasiocarpa* var. *americana, Menyanthes trifoliata, Utricularia intermedia, U. minor, Triglochin maritima, and Drosera intermedia.*

Beltrami Co.: 13.5 mi. NW of W. A., T156N, R32W, Sec. 25, W & G 3023. 12 mi. N of W. A., T156N, R30W, Sec. 18, W & G 3142. 18 mi. NW of W. A., T155N, R33W, Sec. 10, W & G 3181. 25 mi. NW of W. A., T156N, R34W, Sec. 4, W & G 3301. Koochiching Co.: 10.5 mi. NNE of W. A., T156N, R29W, Sec. 16, W & G 3344.

This is the first report from Minnesota supported by voucher specimens, although Hofstetter (1969) observed the plant earlier in the western portion of the Red Lake Peatland. According to Hultén (1968), this circumboreal species has several local extensions into the United States.

Drosera linearis Goldie grows in flarks of the Great Western Patterned Fen but is unknown from the central and eastern portions of the peatland. It is most often associated with *Carex lasiocarpa* var. *americana, Utricularia intermedia, U. minor, Triglochin maritima, Drosera intermedia,* and *D. anglica.*

Beltrami Co.: 20.5 mi. NW of W. A., T155N, R33W, Sec. 5, W & G 3224. 16 mi. NW of W. A., T156N, R32W, Sec. 15, W & G 3249. 25 mi. NW of W. A., T155N, R34W, Sec. 4, W & G 3302.

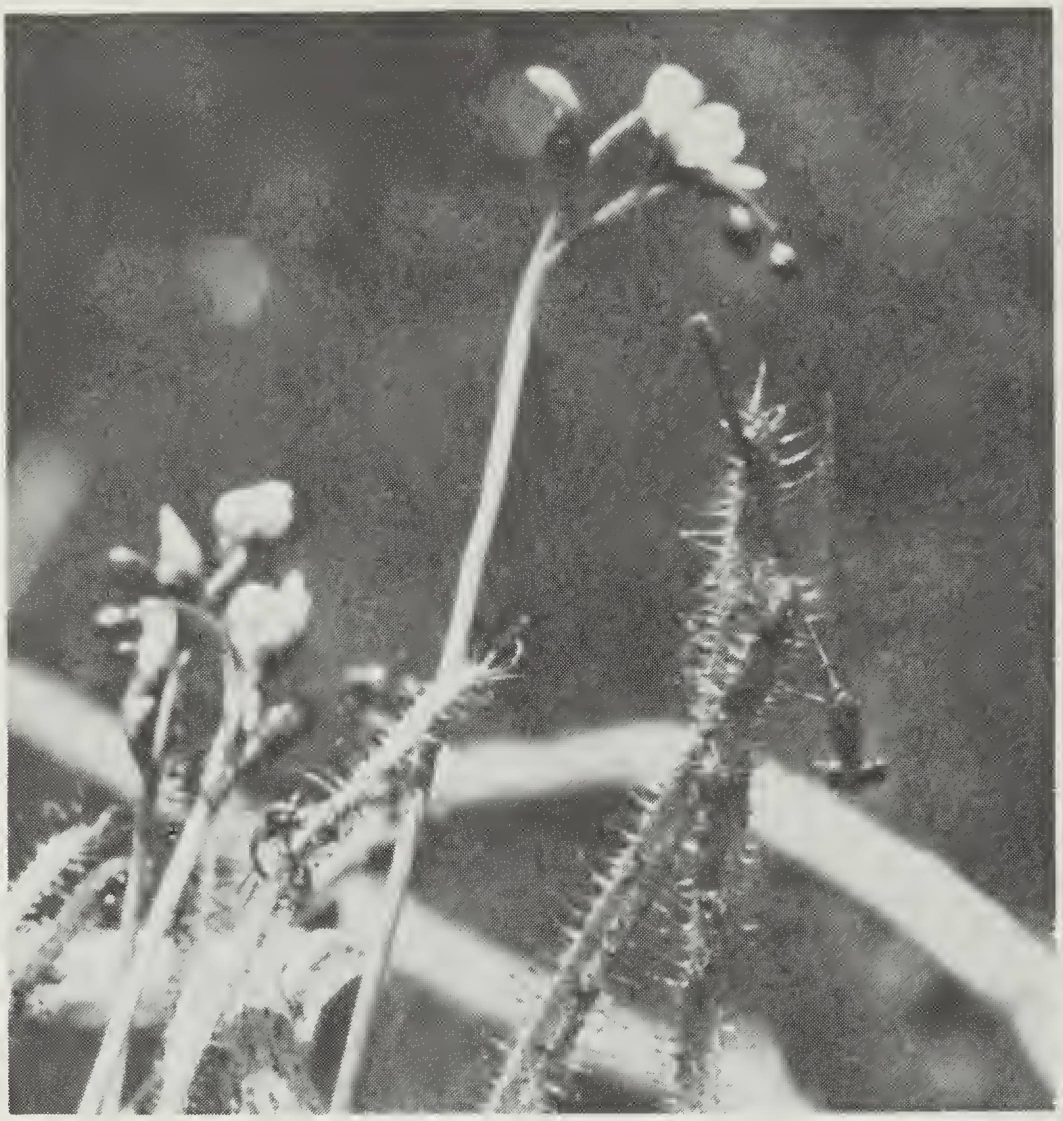

Fig. 2. A flowering example of *Drosera linearis* with its prey.

D. linearis was collected in Hennepin County in 1877 and 1878. Neither of the stations has been relocated. Thus, the peatland collections represent a rediscovery in Minnesota. In Canada, this primarily eastern species ranges from Newfoundland to Alberta (Scoggan, 1978). In the United States, it ranges from Maine as far west as Minnesota (Fernald, 1970), with the peatland providing the westernmost known stations.

Rhynchospora fusca (L.) Ait. f. grows in the flarks of patterned fens (W & G 3015, 3210, 3250) and on the edge of fen pools (W & G 3334, 3354) throughout the peatland, most often associated with *Carex livida* var. *grayana, Rhynchospora alba, Utricularia cornuta, Drosera intermedia,* and *D. anglica.*

Beltrami Co.: 12.5 mi. NW of W. A., T156N, R32W, Sec. 25, W & G 3015. 20.5 mi. NW of W. A., T156N, R33W, Sec. 32, W & G 3210. 16 mi. NW of W. A., T156N, R32W, Sec. 15, W & G 3250. 14 mi. NW of W. A., T156N, R32W, Sec. 24, W & G 3334. Koochiching Co.: 10.5 mi. NNE of W. A., T156N, R29W, Sec. 15, W & G 3354.

Prior to the Red Lake area study, *R. fusca* was known in Minnesota from one locality in St. Louis County. Although the peatland contains the westernmost known stations for this plant in the United States, an isolated station on the Saskatchewan River near the Saskatchewan-Manitoba boundary (Hultén, 1958) is more western.

Carex exilis Dew. is occasional on outer margins of ombrotrophic bogs. These margins receive some nutrients from juxtaposed fens, thus they are higher in pH than the interior of the bogs but lower than the fens. Similar marginal areas described by Sjörs (1963) in the Hudson Bay lowlands of Canada were called by him poor fens. In the Red Lake Peatland, *C. exilis* is most often associated with *Scirpus cespitosus* var. *callosus, Carex chordorrhiza, Eriophorum chamissonis,* and *Habenaria lacera.*

Beltrami Co.: 13.5 mi. NNW of W. A., T156N, R31W, Sec. 17, W & G 2986. 20.5 mi. NW of W. A., T156N, R33W, Sec. 32, W & G 3209. 16 mi. NW of W. A., T156N, R32W, Sec. 15, W & G 3259.

Although previously collected in the peatland area, *C. exilis* is unknown elsewhere in Minnesota. According to Scoggan (1978) and Fernald (1970), the species is known primarily from eastern Canada and northeastern United States and has only limited local populations west of Michigan. The Red Lake Peatland contains the westernmost stations in North America.

Juncus stygius L. var. *americanus* Buchenau was found on the edge of fen pools at three localities where it was associated with *Carex livida* var. *grayana, Rhynchospora alba, Drosera intermedia,* and *Pogonia ophioglossoides.*

Beltrami Co.: 14 mi. NW of W. A., T156N, R32W, Sec. 24, W & G 3295. 15 mi. NW of W. A., T156N, R32W, Sec. 24, W & G 3308. Koochiching Co.: 10.5 mi. NNE of W. A., T156N, R29W, Sec. 16, W & G 3360.

J. stygius var. *americanus* has been known in Minnesota from two localities in St. Louis County. It was first collected in the state in 1886 by J. C. Arthur, L. H. Bailey, and E. W. D. Holway, but owing to scanty label information the station has never been relocated. According to Scoggan (1978), this boreal plant ranges in North America from Alaska to northern Saskatchewan then eastward to Newfoundland with several local extensions into the United States. The peatland stations are the westernmost in the United States.

Cladium mariscoides (Muhl.) Torr. grows in the wettest portions of most, if not all of the patterned fens and is most often associated with *Phragmites australis, Potamogeton gramineus, Utricularia intermedia, U. minor,* and *Menyanthes trifoliata.*

Beltrami Co.: 20.5 mi. NW of W. A., T155N, R33W, Sec. 5, W & G 3184. 16 mi. NW of W. A., T156N, R32W, Sec. 15, W & G 3247.

C. mariscoides was previously known from Clearwater, Pine, Scott, and St. Louis Counties, each with one locality. The Clearwater County collection (5 mi. N or Clearbrook, meadow of old lake bed, T150N, R37W, Sec. 30, Ownbey 4777) represents the westernmost station for this plant in the United States; only one isolated station near Dahlton, Saskatchewan (Scoggan, 1978), is more western.

Pogonia ophioglossoides (L.) Ker fo. *albiflora* Rand & Redfield was found in the flarks of patterned fens at two locations. This is the first report of the taxon from Minnesota.

Beltrami Co.: 12 mi. N of W. A., T156N, R30W, Sec. 18, W & G 3140. 14 mi. NW of W. A., T156N, R32W, Sec. 24, W & G 3296.

The writers wish to thank Prof. Eville Gorham and Prof. Herbert E. Wright, Jr., who so expertly supervised the peatland study; Prof. Gerald B. Ownbey and Prof. Gorham for help with the manuscript; and helicopter pilot Lee Andrews, who landed us throughout the peatland, most areas of which had never before been botanized. The work was supported by a grant from the Minnesota Department of Natural Resources.

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News

A Geobotany Conference on March 1, 1980 at Bowling Green State University will include invited papers on paleobotany, palynology, and ecology, as well as others by interested participants. For information: Dr. Robert C. Romans, Dept. of Biological Sciences, Bowling Green State University, Bowling Green, Ohio 43403.

Botany courses to be offered at the University of Michigan Biological Station in the summer of 1980 include Boreal Flora, Bryophytes, Plant Ecology, Physiological Ecology, and Phycology. For information: Director, Biological Station, University of Michigan, Ann Arbor, 48109.

Erratum: The price of Smith's MICHIGAN TREES WORTH KNOWING (Hillsdale Educational Publishers, Box 245, Hillsdale, Mich. 49242) is $5.50, not the amount which appeared, owing to editorial oversight, in the January issue of the Michigan Botanist.

FOUR ADDITIONS TO THE WISCONSIN FLORA

Neil A. Harriman

Department of Biology
University of Wisconsin—Oshkosh
Oshkosh 54901

Thymelaea passerina (L.) Coss. & Germ. (Thymelaeaceae) is an adventive from Europe heretofore recorded for North America from Kansas, Nebraska, and Iowa (Pohl, 1955; Mcgregor et al., 1972). I now report its occurrence in Wisconsin: Milwaukee County, abundant, in open field of bulldozed clay, and along C&NW RR tracks, in the village of Fox Point, beside Santa Monica Boulevard at Foxdale Road, 6900 North, *Harriman 14126,* 17 August 1977, specimens in OSH, MICH, MIL, WIS, UWM, NY, ASU, OS, PH, and elsewhere. Inquiry to the curators at MIL, WIS, and UWM revealed that they have no records for that plant in Wisconsin. An annual, its abundance suggests it has been established for some time at the site. The waste area habitat makes it likely the plant will spread and become established elsewhere in the *Gray's Manual* range.

Neither in Fernald (1950) nor in Gleason (1952) nor in Gleason & Cronquist (1963) can the plant be keyed, because the representatives of the Thymelaeaceae then known for eastern North America are all shrubby. Indeed, none of these manuals mentions that herbaceous members exist extralimitally. Therefore, it may be useful to append here a description to facilitate recognition: tap-rooted, herbaceous annual, 20-60 cm or more tall, branched or not; the glabrous stems slender and wand-like; leaves alternate, estipulate, plane, linear, articulated at a yellow-cartilaginous base, spreading to erect; flowers 2-3 mm long, 1-3 from the leaf axils, with half to two-thirds of the stem floriferous, each flower subtended by two tiny bracts and arising from a tuft of tiny, glistening white hairs; hypanthium (calyx tube) greenish-yellow, regular, shortly 4-lobed at summit, the lobes scarcely petaloid, appressed hairy; corolla absent; stamens 8, included, inserted in the hypanthium in 2 series, the 4 upper opposite the calyx lobes, the 4 lower alternate with the calyx lobes; pistil with a faintly lateral style and capitate stigma; at maturity, the ovary wall delicate and green, 3-nerved on one side, readily separable from the shiny black seed coat, tapering from a rounded base to a short, appressed-hairy beak, long enclosed in the accrescent hypanthium which becomes brown-membranous, each intact floral unit readily falling from the axis at maturity. Flowering and fruiting August to September, probably until frost. The published record reveals no chromosome count for the species; I counted $2n = 40$ from cells of flower bud primordia (the voucher being my number 14126).

The plant is illustrated very nicely in Pohl's 1955 paper, and its aspect can be seen quite clearly in Negative #263, specimen 503.1, microfiche of the Linnaean Herbarium, the species treated by Linnaeus as *Stellera passerina* L.

In Gleason (1952) and, of course, in Gleason & Cronquist (1963), one finds that on its characters the plant comes to certain apetalous crucifers in the General Keys, section 10; in Fernald (1950), one is led in the Artificial Analytical Keys to a choice involving Chenopodiaceae-Amaranthaceae-*Penthorum*. Since the plant will doubtless be more commonly encountered in the future, it may be useful to make an appropriate marginal note in the manuals.

Kickxia (Scrophulariaceae) has two adventive species in the *Gray's Manual* range, *K. Elatine* (L.) Dum., and *K. spuria* (L.) Dum. Neither is reported to extend into Wisconsin. The genus is not mentioned in Salamun (1951). I report here the occurrence of both in Wisconsin: *Kickxia Elatine* as a garden weed at my home, Winnebago County, section 30, T19N, R17E, 24 July 1969, *Harriman 5056,* with specimens deposited at OSH, MIL, UWM, and WIS. And *Kickxia spuria* as a weed along a fencerow at my home, 20 August 1978, *Harriman 15415,* vouchers at OSH, MIL, UWM, WIS, MICH, and ASU. Thus far, neither species is known to have persisted more than one season, but the specimens are abundantly in flower and fruit, and the plants may be expected as at least casual elements in the state's flora. Both were growing in heavy, fairly moist clays, not in moist sands or loose gravels as is more usual in eastern North America.

Peltandra virginica (L.) Schott & Endlicher (Araceae) is widespread in the eastern and southern United States; Voss (1972) shows it nearly throughout southern Michigan, with a strikingly disjunct station in the Upper Peninsula in the Seney National Wildlife Refuge in Schoolcraft County. It is occasional throughout much of Illinois (Mohlenbrock, 1970) and comes nearest Wisconsin in Cook and Kane Counties (Mohlenbrock & Ladd, 1978). It has long been known from northern Indiana (see, e.g., Pepoon, 1927). I now report it for Wisconsin: Fond du Lac County, abundant in dense clumps, in about a foot of water and four feet of muck, in Spruce Lake, off Airport Road SW¼ NW¼section 23, T14N, R19E, *Underwood 1126,* 9 September 1978, specimens in OSH, MIL, UWM, and WIS; the curators of the latter three herbaria assure me they hold no other records for the plant in Wisconsin.

Spruce Lake is a bog lake, with a goodly portion of its periphery a state scientific area. However, about 1/10 of the shoreline remains in private hands and is used in the fall for duck hunting. A number of artificial nesting boxes for wood ducks have been erected along that shoreline. Martin & Uhler (1939) characterize *P. virginica* as a species that "has given little evidence of value to ducks other than a few wood ducks." This comment, together with the nesting boxes, raises the possibility that the plants were artificially introduced to this site. In the files of the Wisconsin Scientific Areas Preservation Council, there is a report on a visit to the Spruce Lake Bog Scientific Area dated 9 June 1977, in which qualified botanists make no mention of the occurrence of this species, even though several large clumps occur at the edge of the boardwalk that traverses a small portion of the bog. I myself did not detect it on a visit to the bog and lake in July, 1978, perhaps dismissing it with a casual glance as a *Pontederia*. Its abundance in the lake, despite the absence of reports of it there, makes it evident that the plant is long established. Modlin (1970) in a survey of lake vegetation that covered much of the Lake Michigan drainage of southeastern Wisconsin does not report the plant, either. Whatever the mode of establishment may have been, the plants are so thoroughly established and abundantly fruitful that they can be expected to spread into suitable habitats throughout Wisconsin.

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Review

TREES, SHRUBS AND FLOWERS TO KNOW IN ONTARIO, by Sheila McKay & Paul Catling with illustrations by Betsy Gordon. J. M. Dent & Sons [Toronto], 1979. 208 pp. $6.95 (Canadian).

This book discusses and illustrates about 442 species with text notes about dozens of others. The illustrations are line drawings, and for each species there are about 15-20 lines of print. The subdivisions in the text are by habit—e.g., conifers, trees, small trees or shrubs, shrubs, vines, and herbs. The herbs are subdivided according to flower color. Three pages are devoted to aquatics and one page each to grasses, sedges, grass-like plants, arums, and saprophytes and parasites. Identification beyond this point is by comparison with illustrations and text. Inclusion of species is based primarily on how frequently the plant is met with in the more populated parts of Ontario.

The illustrations are good, accurately conveying the appearance of the plant. One can quibble over only a few minor details. The drawing of *Tragopogon pratensis* does not show the cirrhose-recurved leaf tips so characteristic of that species nor does the drawing of *Polygonum lapathifolium* display the nodding inflorescences noted in the text. The text provides hints on identification that will be useful to people beyond beginners, as will notes on habitat, distribution, flowering times, economic and horticultural uses, folklore, and pollination.

Particularly useful features are discussions of the vegetation and floristic zones of Ontario, a reference list (although The Michigan Botanist was left off the list of journals relating to the Ontario flora!), and the suggestion that confirmation of identifications may be obtained by sending specimens to professionals in universities and museums. Gratifyingly, the book does not shy away from plant groups with a reputation for difficulty like willows, blackberries, hawthorns, and serviceberries but rather gives a much needed introduction to them.

The type face is clear, and the text is quite free of typographical and other errors (although people should note that on p. 154 the name of the fringed Polygala should be paucifolia not pauciflora). The book has a flexible, water-resistant paper cover that seems securely attached. It is a fine book well suited to its stated objective, that of enabling a beginning botanist to identify and learn something about the most common wild plants of Ontario.

—A. A. Reznicek

INDEX TO VOLUMES 16–18

This index is intended to be complete only for topics. Species given incidental mention or included in floristic lists are not given below. Illustrations are indicated by an asterisk.

Agropyron repens 16:174, 181*
Agrostis gigantea 16:173, 184*
algae of Wisconsin 18:37–41
Allegan Co., addition to flora 16: 26; Scleria reticularis in 16:63–65
allelopathy 16:15–18
Alopecurus pratensis 16:170, 180*
Andresen, N. A. & E. F. Stoermer, The diatoms of Douglas Lake—a preliminary list 17:49–54
aquatic plants of Douglas Lake 17:183–191
asexual reproduction in Sphagnum 16:83–89
aspens and birches, hybrids 17:167–172; pollen abortion 17:167–172
aspens, variation 17:141–153
aspen stand described (Cheboygan Co.) 17:73–79

Baetsen, R. H., The impact of snowmobiling on ground layer vegetation near Sage Lake, Ogemaw County, Michigan 16:19–25
Baker Woodlot, MSU, history and physical description 18:123–136
Barnes, B. V., Pollen abortion in Betula and Populus (section Leuce) 17:167–172; see Farmer & Barnes
Barrows, E. M., Flower biology and arthropod associates of Lilium philadelphicum 18:109–115*
Beach, J. H. & W. D. Stevens, A study of Baker Woodlot I. Physical and historical description 18:123–136
Beaman, J. H., Commentary on endangered and threatened plants in Michigan 16:110–122; photograph 18:43; see Benninghoff & Beaman, also Wagner et al.
beech-maple woods, Kalamazoo Co., compared with oak openings in Michigan and Illinois 16:151–155; vegetation change 16:201–210
Begres, F. M. (see Hoagland)
Beitel, J. M., The clubmosses Lycopodium sitchense and L. sabinifolium in the Upper Great Lakes region 18:31–13*; see also Wagner & Beitel

Benninghoff, W. C. & J. H. Beaman, Contributions to botany by members of the Michigan Botanical Club 18:82–83
Betula hybrids 17:167–172; pollen abortion 17:167–172
birches and aspens, hybrids 17:167–172; pollen abortion 17:167–172
birch-maple woods, succession altered by wind 18:83–87
blind, key to broadleaf trees for 18:117–119
bog succession (Cheboygan Co.) 18:59–68, 91–98; water level and tree mortality 18:91–98
Böhlke, M. W. (see Voss)
Boletus sphaerocystis, a little known edible bolete 18:27–29*
Bourdo, E. A. (see Wagner)
Braham, R. R., Crown position and heterophylly in white oak 16:141–147
Brasenia schreberi, trichomes 17:83–91*
breeding systems in Plantago 16:78
Bromus tectorum 16:171, 179*
Bruggers, S. G. & P. Van Faasen, Additions to the flora of Allegan County 16:26
Buck, W. R., Ptychomitrium, a moss genus new to Michigan 17:162; see Harris & Buck

Candelariella in the Mackinac Straits region 17:155–161*; aurella 17:160–161; efflorescens 17:155–161*; vitellina 17:160–161; xanthostigma 17:155–161*
Carex exilis 18:140
Carlson, T. J., The comparative ecology and frequencies of interspecific hybridization of Michigan woodferns 18:47–56*
Case, F. W. (see Wagner)
Cass Expedition 17:25–30
Cenchrus longispinus 16:176, 188*
Chau, R., Conidial ultrastructure and taxonomic affinity of a fungal parasite of Sphagnum 18:15–18*
Cheboygan Co., aquatic plants of Douglas Lake 17:183–191; bog succession 18:59–68, 91–98; aspen stand, description 17:73–79; diatoms 17:49–54; fen succession 18:59–68; vascular plants 16:126–140; woodferns 18:47–56
chemical inhibition 16:15–18
chromosomes of mosses of Douglas Lake region 16:51–55
Chrysosphaerella coronacircumspina 16:191, 192*, 194*
Chrysophyceae in Michigan 16:191–195
Churchill, J. A. (see Wagner)
Cladium mariscoides 18:141
Cladonia invisa, synonym of C. caespiticia 16:159
coastal plain disjuncts 16:113
Coffman, M. S., Eastern hemlock germination influenced by lights, germination media, and moisture content 17:99–103
Collybia racemosa, dimorphism 16:65–72*
Conocephalum conicum 16:96*
conidial ultrastructure in Tilletia sphagni 18:15–18*
Contributions to botany by members of the Michigan Botanical Club 18:82–83
copper tailings, affect on alfalfa seedlings 17:173–177
Crawford Co., Dalibarda repens 16:189–190
crown position and heterophylly in white oak 16:141–147
Crum, H., An expanded description of Sphagnum splendens 18:69–72
Cyperus hybrids 17:70

Dabydeen, S. & R. G. Koch, Vegetation and floristics of a sand spoil deposit—Barker's Island in Superior Harbor, Douglas County, Wisconsin 16:39–46
Dactylis glomerata 16:171, 181*
Dalibarda repens in Crawford Co. 16:189–190
Dean, P. A. & F. H. Erbisch, Comparison of roots and stems of alfalfa seedlings grown on soil and copper tailings 17:173–177
Delta Co., pollen analysis 16:55–62
diatoms of Douglas Lake 17:49–54; of Wisconsin (Vilas Co.) 17:113–117; 18:37–41; of Tiplady Bog, Livingston Co. 17:55–64
Digitaria sanguinalis 16:175, 188*
dimorphism in Collybia racemosa 16:65–72*
Douglas Co. (Wis.), flora of sand spoil deposit 16:43–45
Douglas Lake, additions and corrections to flora 16:126–140; aquatic plants 17:183–191; chromosome numbers of mosses 16:51–55; diatoms 17:49–54

Douglass, D. B. 17:25–30
Drosera anglica 18:139; linearis 18:140
Dryopteris ecology and hybridization 18:47–56; celsa 18:47*, 49; clintoniana 18:47*,49, 51–53; 18:47*, 48, 51–53; expansa 18:47*, 49; filix-mas 18:47*, 50; fragrans 18:47*, 50; goldiana 18:47*, 49, 51–53; intermedia 18:47*, 48, 51–53; marginalis 18:47*, 49, 51–53; 18:47*, 48, 51–53
dyeing with plants 16:3–14

Echinochloa crusgalli 16:177, 186*
Emmet Co., vascular plants 16:126–140; woodferns 18:47–56
Endangered, threatened, and rare vascular plants in Michigan 16:99–122
Entoloma vernum 16:196
Epipyxis kenaiensis 16:193, 194*
Eragrostis cilianensis 16:176, 186*
Erbisch, F. H. (see Dean)

Farmer, M. M. & B. V. Barnes, Morphological variation of families of trembling aspen in southeastern Michigan 17:141–153
fen succession (Cheboygan Co.) 18:59–68; water chemistry 18:67
Fenwick, M. G. (see Lipsey)
Festuca pratensis 16:172, 183*; rubra 16:173, 183*
Fink, B., Minnesota itinerary 17:103–112*
Fissidens fontanus 18: 25; grandifrons 18:25
Fleckenstein, M. & R. W. Pippen, A prairie grove in southwest Michigan 16:147–158; see also Ponchillia & Fleckenstein
floodplain vegetation (Saginaw) 17:91–99
floral biology, Lilium philadelphicum 18:109–115*; Plantago 16:73–83
Folwell, N. W. 17:177–182
Fontinalis in Houghton Co. 16:123–125
Freckmann, R. W., New or noteworthy taxa for central Wisconsin in the flora of the "Whiting Triangle" 17:65–72
Frye, D. M., A botanical inventory of Sandhill Woodlot, Ingham Co. III. Phenological study 16:34–38

gamete dispersal distances, in mosses 18:73–81
Gannon, J. E. (see Sanger)
gene flow distances, in mosses 18:73–81
Gentry, J. L., Current status of the genus Hackelia (Boraginaceae) in Wisconsin 17:48
Gereau, J. F. (see Glime)
germination, Tsuga, 17:99–103
Glaser, P. H. (see Wheeler)
Glime, J. M. & J. F. Gereau, Some unusual Fissidens collections from Michigan's Upper Peninsula 18:25–26; & S. E. Trynoski, Several interesting Fontinalis collections in Houghton County, Michigan 16:123–125
Gorton, P. B. & D. & K. Townsend, Dalibarda repens confirmed in Michigan 16:189–190
grasses, common 16:167–188*
Gray, Asa, correspondence with N. W. Folwell 17:177–182
Gretz, M. (see Wujek)

Hackelia in Wisconsin 17:48; deflexa var. americana 17:48; floribunda 17:48
Harriman, N. A., Four additions to the Wisconsin flora 18:143–145
Harris, R. C., An overlooked Cladonia name in North America 16:159; The genus Placidiopsis Beltr. (lichenized Ascomycetes) new to North America as Placidiopsis minor sp. nov. 18:57–58*; & W. R. Buck, Lichens of the Mackinac Straits region. II. Candelariella Müll. Arg. 17:155–161
Haynes, R. R. & C. B. Hellquist, The distribution of the aquatic vascular flora of Douglas Lake, Cheboygan County, Michigan 17:183–191
Hellquist, C. B. (see Haynes)
Helotium schimperi 18:15–18
hemlock germination 17:99–103
heterophylly in white oak 16:141–147
Hieracium in Michigan 17:35–47; hybrids 17:40, 44; aurantiacum 17:39–42; caespitosum 17:36–38, 40; flagellare 17:39; florentinum 17:36–38; pilosella 17:38–40; piloselloides 17:36–38, 42; praealtum 17:36–38; pratense 17:36–38
Hoagland, K. D. & F. M. Begres, The diatom flora of Tiplady Bog, Michigan 17:55–64
Hordeum jubatum 16:174, 182*
Houghton Co., Fontinalis 16:123–125

hybridization in Lycopodium 18:3–13; Solidago 18:31–35; Cyperus 17:70, Lysimachia 17:70–71; Plantago 17:70; Hieracium 17:40, 44; birches and aspens 17:167–172; woodferns 18:47–56

Illinois, ravine flora along Lake Michigan (Lake and Cook Cos.) 17:123–140
Ingham Co., phenology of Sandhill Woodlot 16:34–38
Iris lacustris 16:164*

Jeffersonia diphylla 18:120*
Juncus stygius var. americanus 18:141

Kalamazoo Co., prairie peninsula 16:147–158; vegetation change in beech-maple woods 16:201–210
Kapp, R. O., Presettlement forests of the Pine River Watershed (central Michigan) based on original land survey records 17:3–15; see also Wheeler & Kapp; & T. P. Means, Pollen analysis of peat from a sinkhole in the Garden Peninsula, Delta County, Michigan 16:55–62
Kendrick, B. (see Watling)
key to trees designed for blind 18:117–119
Keweenaw Co., Fissidens 18:25–26
Kickxia elatine 18:144; spuria 18:144
Koch, R. G. (see Dabydeen; also Kapustka)

LaBatt, D. 18:43*
Lane, D. M., Extent of vegetative reproduction in eleven species of Sphagnum from northern Michigan 16:83–89
LaRue, J. I., Natural dyeing with plants in Michigan 16: 3–14
Laser, K. D., A scanning electron microscope study of the trichomes in Brasenia schreberi 17: 83–91
life forms in Michigan 16: 26–33
Lilium philadelphicum, pollination 18: 109–115*
Lipsey, L. L. & M. G. Fenwick, Investigations on the freshwater algae of Wisconsin I. Plankton diatoms from High Lake (Vilas County) 17:113–117; II. 18:37–41
Livingston Co., diatoms 17:55–64
Lolium perenne 16:172, 181*
Lycopodium flabelliforme, strobilus variation 18:19–23*; sabinifolium and L. sitchense in the Upper Great Lakes region 18:3–13*; sitchense 16:212; tristachyum 18:4, 5*, 10*, 12*
Lysimachia hybrids 17:70–71

Mallomonas elongata 16:191, 192*
Means, T. P. (see Kapp)
Mesler, M. R., Notes on the floral biology of Plantago in Michigan 16:73–83
Michigan Botanical Club, contribution to botany by members 18:82–83; Plants in Print 16:94–95, 160–163; 17:163–166; 18:30, 36, 42
Minnesota, Fink's lichen collections 17:103–112; vascular plants of Red Lake Peatland 18:137–141
Moran, R. C., Vascular flora of the ravines along Lake Michigan in Lake County, Illinois 17:123–140
Morchella esculenta 17:80*
Morton, J. K., Observations on Houghton's Goldenrod (Solidago houghtonii) 18:31–35
Moore, W. O., Some very common grasses 16:167–188*
Muhlenbergia frondosa 16:178, 187*; schreberi 16:178, 187*

Nolanea verna in North America 16:195–200*

oak opening, Kalamazoo Co., comparison with beech-maple woods and with prairie in Illinois 16:147–158
oak, white, crown position and heterophylly 16: 141–147
Ogemaw Co., impact on snowmobiling 16: 19–25
Olexia, P. 18: 43*
Osteomorpha fragilis 16:69*
Ovrebo, C. & A. H. Smith, Studies in Tricholoma vaccinum and T. imbricatum in North America 18:99–108

palynology, Delta Co. 16:55–63
Panicum capillare 16:177, 185*
Paterson, R. L., History of recent habitat changes in central Michigan 17:15–23
Peltandra virginica 18:144
Phalaris arundinacea 16:173, 182*
phenology, Sandhill Woodlot, Ingham Co. 16:34–38
Phleum pratense 16:173, 183*
Pierce, G. J. & R. W. Pippen, Scleria reticularis new to the Michigan flora 16:63–65

Pilobolus 17:32*
Pine River watershed, presettlement forests 17:3–15
Pippen, R., photograph 18:43*; see Fleckenstein & Pippen, also Pierce & Pippen and Zager & Pippen
Placidiopsis minor, genus and species new to North America 18:57–58*
Plantago hybrids 17:70; aristata, pollination 16:73–83, 75*; lanceolata, pollination 16:75*, 78–80; patagonica, pollination 16:73–83; virginica, pollination 16:73–83, 77
Pleurotus dryinus 16:67* 70, 71
Pleurozium schreberi, sex ratios and fruiting 18:73–81*
Poa annua 16: 170, 180*; compressa 16: 174, 185*; pratensis 16: 171, 180*
Pogonia ophioglossoides 18:141
Pollen abortion in Betula and Populus (section Leuce) 17:167–172; analysis from sinkhole, Garden Peninsula, Delta Co. 16:55–62
pollination, Lilium philadelphicum 18:109–115; Plantago 16:73–83*
Ponchillia, P. E. & M. H. Fleckenstein, Common broadleaf trees of southwestern Michigan: a key designed for blind persons 18:117–119
Populus hybrids 17:167–172; pollen abortion 17:167–172; description of stand in Cheboygan Co. 17:73–79; tremuloides, variation 17:141–153
prairie peninsula 16:147–158
presettlement forests of central Michigan 17:3–21
Ptychomitrium incurvum new to Michigan 17:162
Publications of interest 16:92–93; 17:154

Quebec, Cladonia invisa 16:159; Sphagnum splendens redescribed 18:69–72

ravine flora along Lake Michigan, Illinois 17:123–140
reproductive biology in mosses 18:73–81
revegetation on sand spoil deposit (northern Wis.) 16:39–46
Reviews: Nova Scotian Boletes 16:38; Spring Flora of Wisconsin 16:90; Leguminosae of the United States: II. Subfamily Caesalpinoidae 16:91; Vegetation and Flora of the Huron Mountains 16:91; Sedges. Cyperus to Scleria. The illustrated flora of Illinois 16:91; Once Around the Sun: a Door County Journal 16:163; Northland Wild Flowers. A guide for the Minnesota region 17:24; The Flora of Manitoulin Island 17:48; The Life of Isle Royale 17:48; Common Plants, Botanical and Colloquial Nomenclature 17: 118–119; Toxic and Hallucinogenic Mushroom Poisoning: a Handbook for Physicians and Mushroom Hunters 17:119; Wildflowers of Michigan 18:14; The Witch's Garden 18:14; Intermountain Flora, Vascular Plants of the Intermountain West, U. S. A. 18:116; Michigan Trees Worth Knowing 18:24; Botanical Beachcombers and Explorers 18:24; Trees, Shrubs and Flowers to know in Ontario 18:145
Rhodophyllus vernus 16:196
Rhus glabra, chemical inhibition 16:15–18
Rhynchospora fusca 18:140

Saginaw, floodplain vegetation 17:91–99
sand spoil deposit, vegetation (northern Wisconsin) 16:39–46
Sanger, R. & J. E. Gannon, Vegetation succession in Smith's Bog, Cheboygan County, Michigan 18: 59–68*
Sandhill Woodlot, Ingham Co., phenology 16:34–38
Schweinitz Herbarium, types from Cass Expedition 17:25–30
Schwintzer, C. R., Vegetation changes following a water level rise and tree mortality in a Michigan bog 18: 91–98
Scleria reticularis new to Michigan 16:63–65
Sclerostilbum septentrionale 16:65, 67*, 69*
seed germination, Tsuga 17:99–103
Setaria viridis 16:175, 186*
sex ratios and fruiting in Pleurozium 18:73–81
Smith, A. H., Stropharia riparia, a previously undescribed species suspected of occurring in Michigan 18: 107–108*; see Ovrebo & Smith
Snider, J. A., Chromosome studies of some mosses of the Douglas Lake region. IV. 16:51–55
snowmobiling, impact on vegetation 16:19–25
Solidago houghtonii 18:31–35*
Sphagnum, infected by Tilletia sphagni 18:15–18; splendens, description 18:69–72*; vegetative reproduction 16:83–89
Stephensen, A. G., The chemical inhibition of competitors by smooth sumac (Rhus glabra) 16:15–18
Stevens, W. D. (see Beach)
Stoermer, E. F. (see Andresen)

Stoneburner, A., Fruiting in relation to sex ratios in colonies of Pleurozium schreberi in northern Michigan 18:73–81
Strally, J. 18:43*
Stropharia riparia, new species 18:107–108*
strobilus variation in Lycopodium flagelliforme 18:19–23*
Stuckey, R. L., David Bates Douglass' plants from the Cass Expedition in the Schweinitz Herbarium 17:25–30; Nathan Wright Folwell, Asa Gray's botanical correspondent in Michigan 17:177–182
succession, acceleration due to high wind 18:83–87; beech-maple woods 16:201–210; birch-maple woods 18:83–87; bog (Cheboygan Co.) 18:59–68, 91–98
surveyors' records of early vegetation in central Michigan 17:3–15
sycamore 18:88*
Synura spinosa fo. mollispina 16:191, 192*

Thieret, J. W., Life forms in the Michigan flora 16:27–33
Thompson, P. W. (see Wagner)
threatened plants 16:118–121
Thymelaea passerina 18:143
Tilletia sphagni, conidial ultrastructure 18:15–18
Tiplady Bog (Livingston Co.), diatoms 17:55–64
Tittabawassee floodplain (Saginaw), vegetational patterns 17:91–99
Townsend, D. & K. (see Gorton)
trembling aspen, variation 17:141–153
Tricholoma imbricatum 18:99–108*; vaccinum 18:99–108*
Trynoski, S. E. (see Glime)
Tsuga canadensis, germination 17:99–103
twinflower, 18, 120*

Van Faasen, P. (see Bruggers)
variation in aspens 17:141–153
vegetation change, Cheboygan Co. bogs 18:59–68, 91–98; in central Michigan since settlement 17:3–21
vegetative reproduction in Sphagnum 16:83
Virginia (Highland Co.), Placidiopsis minor 18:57–58
Voss, E. G., Additions and corrections to the list of vascular plants from the Douglas Lake region, Michigan 16:126–140; see Wagner et al.; & Böhlke, The status of certain hawkweeds (Hieracium subgenus Pilosella) in Michigan 17:35–47

Wagner, W. H. & J. M. Beitel, Strobilus variation in clones of running pine, Lycopodium flabelliforme 18:19–23*; et al., Endangered, threatened, and rare vascular plants in Michigan 16:99–110
Washtenaw Co., white oaks, crown position and heterophylly 16:141–147
water chemistry in fen 18:67; level and bog succession 18:91–98
Watling, R. & B. Kendrick, Dimorphism in Collybia racemosa 16:65–72
Weber, N. S., Boletus sphaerocystis, a little-known edible bolete 18:27–49*
Wells, J. R., Tree populations of a mature aspen forest in Cheboygan County, Michigan 17:73–79
Whiting, R. E., photograph 18:43*
Wheeler, G. A. & P. H. Glaser, Notable vascular plants of the Red Lake Peatland, northern Minnesota 18:137–141
Wheeler, R. H. & R. O. Kapp, Vegetational patterns on the Tittabawassee floodplain at the Goetz Grove Nature Center, Saginaw, Michigan 17:91–99
wind, acceleration of succession 18:83–87
Wisconsin, addition to the flora 18:143–145; Boletus sphaerocystis 18:27–29; succession in birch-maple woods 18:83–87; Douglas Co., flora of sand spoil deposit 16:43–45; Fond du Lac Co., Peltandra virginica 18:143; Milwaukee Co., Thymelaea passerina 18:141; Portage Co., noteworthy plants 17; 65–72; Vilas Co., algae 17:113–117; 18:37–41; Winnebago Co., Kickxia elatine and K. spuria
woodferns, ecology and hybridization 18:47–56
Wujek, D. E., M. Gretz & M. G. Wujek, Studies on Michigan Chrysophyceae. IV. 16:191–195*
Wujek, M. G. (see Wujek et al.)

Xyris montana 18:000

Zager, P. E. & R. W. Pippen, Fifteen years of change in a southwest Michigan hardwood forest 16:201–210

The May issue (Vol. 18, no. 3) was mailed June 14, 1979.

CONTENTS

A Study of Baker Woodlot I. Physical and Historical Description
James H. Beach and W. D. Stevens 123

Notable Vascular Plants of the Red Lake Peatland, northern Minnesota
Gerald A. Wheeler and Paul H. Glaser 137

News 142

Four Additions to the Wisconsin Flora
Neil A. Harriman 143

Review 145

Index to Volumes 16–18 146

On the cover: A swampy depression
in Baker Woodlot, late winter or early spring
(photo by Hannah Priwer)

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